SR 3 MP 49.48 Big Scandia Creek (996804): Preliminary Hydraulic Design Report

JULIE HEILMAN, PE (FPT20-03166)
STATE HYDRAULIC ENGINEER
Y-12554 Olympic Region GEC

Sulochan Dhungel, P.E., Lead Design Engineer,
David Evans and Associates, Inc. (FPT20-37787)

Josh Owens, P.E., Geomorphologist,
David Evans and Associates, Inc.

Bryan Darby, Biologist,
David Evans and Associates, Inc. (FPT20-39955)

Americans with Disabilities Act (ADA) Information

Materials can be made available in an alternative format by emailing the WSDOT Diversity/ADA Affairs Team at wsdotada@wsdot.wa.gov or by calling toll free: 855-362-4ADA (4232). Persons who are deaf or hard of hearing may contact that number via the Washington Relay Service at 7-1-1.

Title VI Notice to Public

It is Washington State Department of Transportation (WSDOT) policy to ensure that no person shall, on the grounds of race, color, national origin, or sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally funded programs and activities. Any person who believes his/her Title VI protection has been violated may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For Title VI complaint forms and advice, please contact OEO's Title VI Coordinator at 360-705-7082 or 509-324-6018.

Contents

Figures

Tables

This page intentionally blank

1 Introduction

To comply with United States et al. vs. Washington, et al. No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas [WRIAs] 1 through 23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 3 crossing of Big Scandia Creek at milepost (MP) 49.48 within WSDOT's Olympic region. The existing structure at that location has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (site identifier [ID] 996804) and has an estimated 6,312 linear feet of habitat gain.

Per the federal injunction, and in order of preference, fish passage should be achieved by (1) avoiding the necessity for the roadway to cross the stream, (2) use of a full-span bridge, or (3) use of the stream simulation methodology. WSDOT evaluated the crossing using the stream simulation method because of the relatively small bankfull width (10 feet) and the confined nature of the channel.

The crossing is located in Kitsap County, 5 miles north of Silverdale, Washington, in WRIA 15. The highway runs in a north-south direction at this location and is about 1.6 miles from the outlet of Big Scandia Creek at Liberty Bay. Big Scandia Creek generally flows from west to east beginning at the confluence of two of its tributaries about 350 feet upstream of the SR 3 crossing (see Figure 1 for the vicinity map).

The proposed project will replace the existing 202.5-foot-long, 54-inch-diameter corrugated steel culvert with a structure designed to accommodate a minimum hydraulic width of 19 feet. The proposed structure is designed to meet the requirements of the federal injunction using the stream simulation design criteria as described in the 2013 WDFW Water Crossing Design Guidelines (WCDG) (Barnard et al. 2013). This design also meets the requirements of the WSDOT Hydraulics Manual (WSDOT 2022). Structure type is not being recommended by WSDOT Headquarters Hydraulics and will be determined by others at a future design phase.

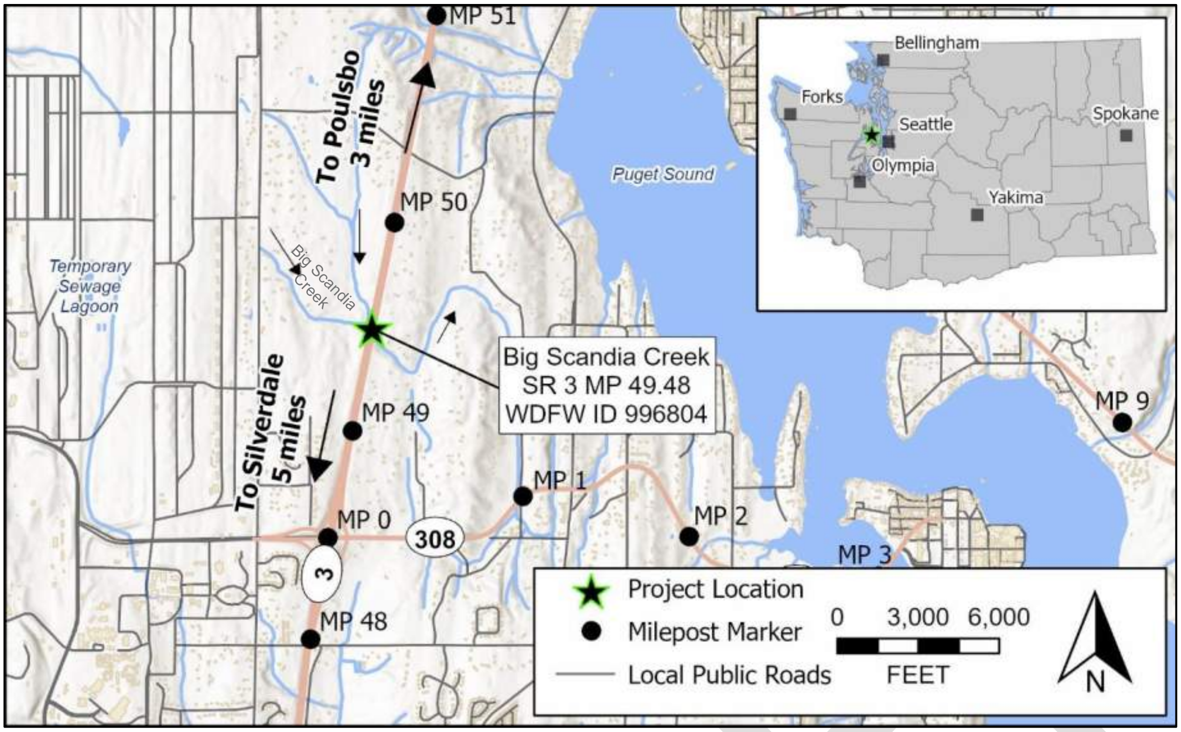


Figure 1: Vicinity map

2 Watershed and Site Assessment

The existing watershed was assessed in terms of land cover, geology, regulatory floodplains, fish presence, site observations, wildlife crossing priority, and geomorphology. This was performed using a site visit and desktop research with resources such as the United States Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and WDFW, and past records like observations, maintenance, and fish passage evaluation.

2.1 Site Description

The culvert under SR 3 at MP 49.48 (Site 996804) for the Big Scandia Creek is listed as a barrier due to outfall drop. The outfall at the downstream side drops by 0.8 foot. This drop restricts salmonid migration up and down the stream. Fine sediments settle in the pool created by the drop, and eddies in the pool scour the channel at this section, releasing sediments into the system. This crossing is not listed as a Chronic Environmental Deficiency or failing structure (WSDOT 2020). There was no visible maintenance activity noted during the site visit, and no maintenance records were available. Flooding history of the site was not available in any relevant reports and literature, and no high-water marks were evident around the site. The total length of potential habitat gain for Site 996804 is 6,312 linear feet according to the WDFW Fish Passage and Diversion Screening Inventory Database (FPDSI, 2021) for this site.

2.2 Watershed and Land Cover

Big Scandia Creek at SR 3 drains approximately 652.8 acres through two tributaries that join from the west and north (see Figure 2). The watershed of the contributing basin above the existing culvert was delineated by reviewing the topographical data obtained from Light Detection and Ranging (LiDAR) survey data (see Figure 2). The basin extends from high points along Gunard Road on the west to SR 3 to the east. Aerial imagery shows that the contributing watershed is a mix of urban land use in the headwaters and forested land use near the crossing (Google Earth 2021). The upstream area of the basin has gentle slopes where the headwater stream flows through partially developed areas mixed with lightly forested areas. Runoff from these areas flows on the streets and developed spaces. According to the National Land Cover Dataset for 2019 (Dewitz, 2021), the watershed contains about 56 percent forest and 37 percent developed land cover types (see shading on Figure 3). Table 1 presents a detailed estimate of the land use percentages. The maximum elevation of the basin is 495 feet in North American Vertical Datum of 1988 (NAVD 88) and descends to 312 feet (NAVD 88) at the crossing. The overall basin has mild slopes that average less than 10 percent. The crossing itself has an average slope of about 1.5 percent. Urban areas have higher velocities of runoff and thus provide more sediment to the outlet. Milder slopes and runoff from developed areas upstream might have influenced the present state of the stream, where fine sediments are abundant at the crossing. The basin receives an annual average of 41.8 inches of precipitation (PRISM Climate Group 2021).

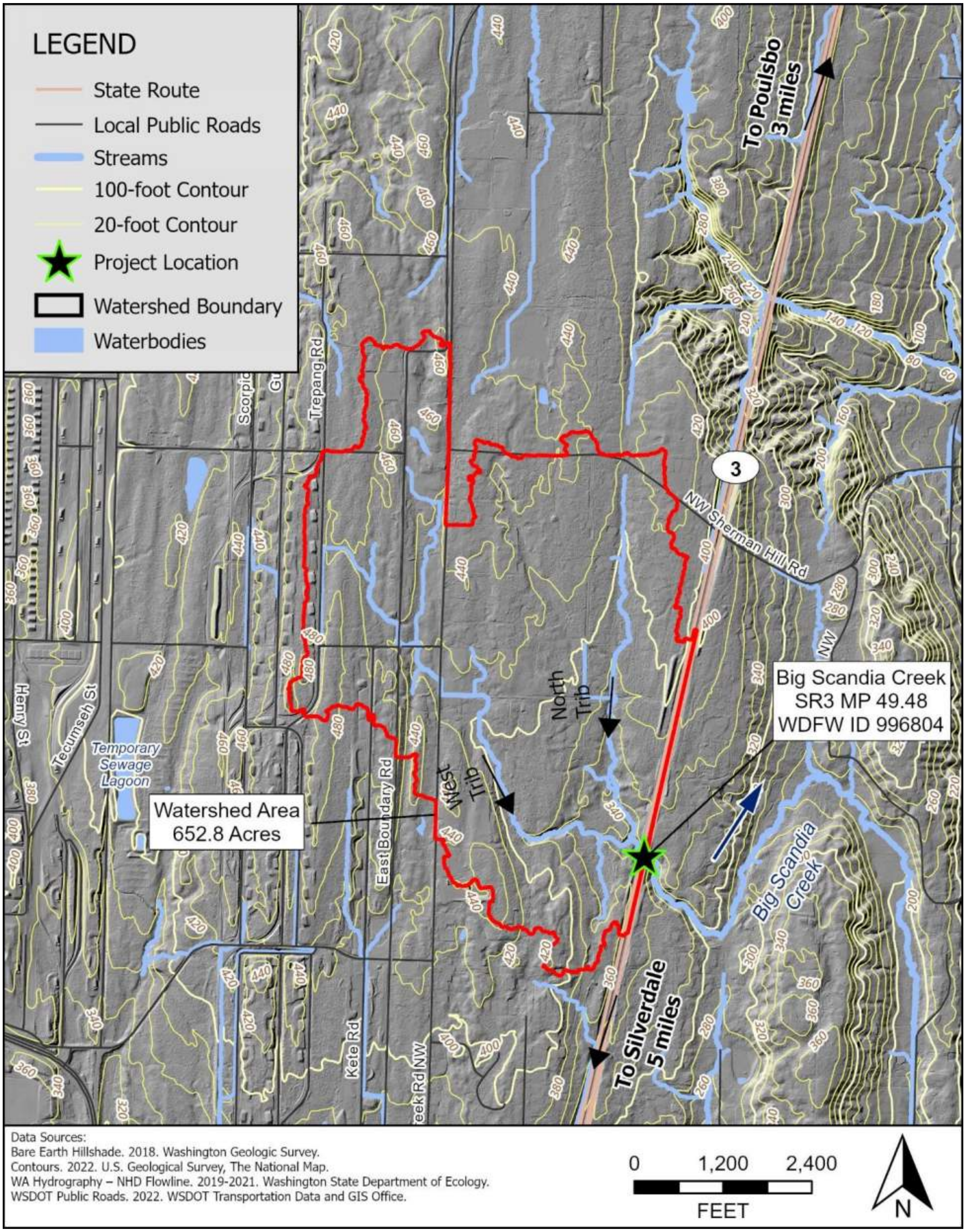


Figure 2: Watershed map

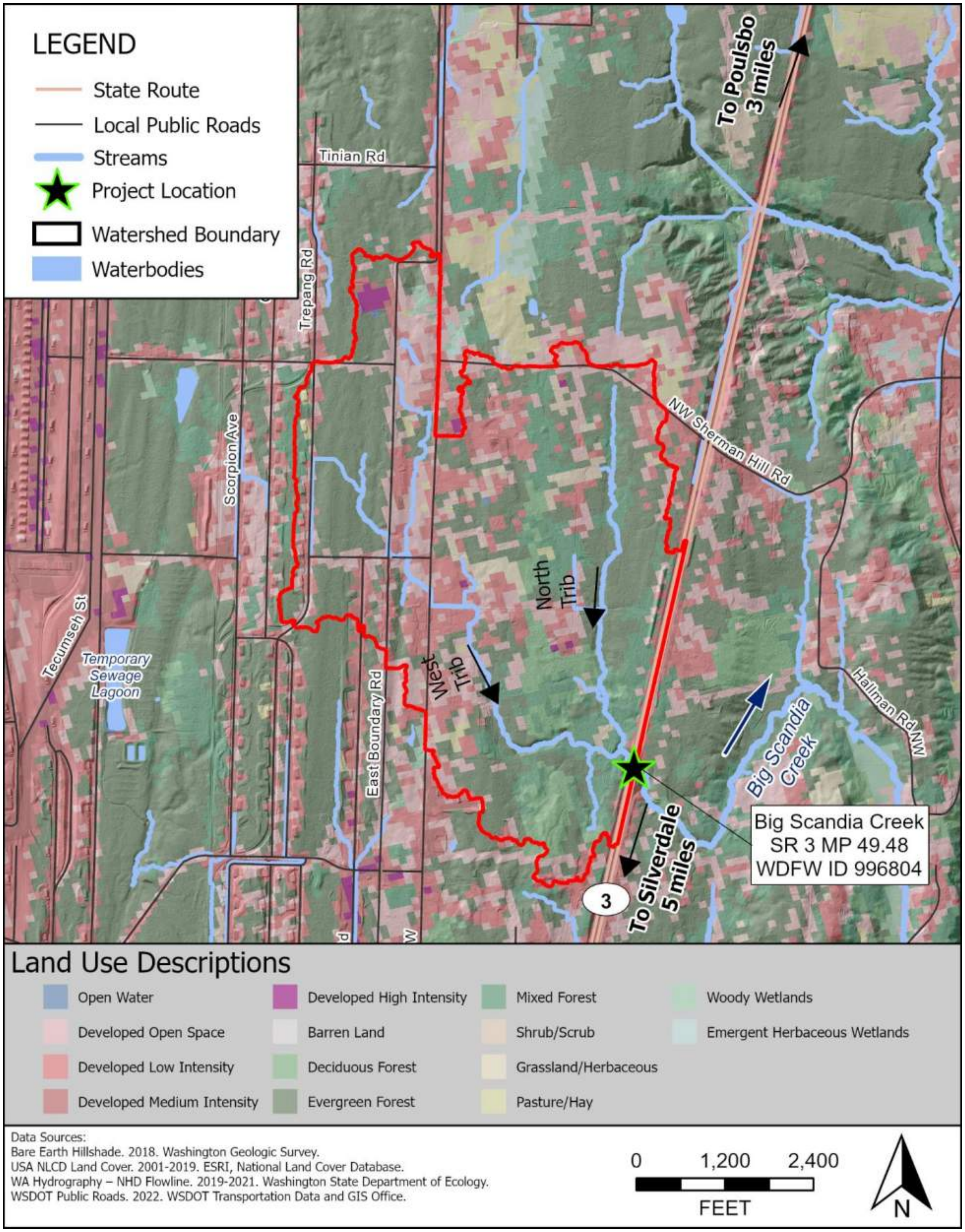


Figure 3: Land cover map (NLCD 2019)

Table 1: Land cover

Land cover class	Basin coverage (percentage)
Evergreen Forest	37.8
Developed, Open Space	17.3
Developed, Low Intensity	16.1
Mixed Forest	13.6
Deciduous Forest	6.1
Developed, Medium Intensity	4.0
Shrub/Scrub	1.9
Herbaceous	1.3
Hay/Pasture	0.9
Developed, High Intensity	0.7
Woody Wetlands	0.3
Open Water	0.1

2.3 Geology and Soils

Site 996804 is located generally on the Kitsap Peninsula, which consists of glaciated surfaces that are fluted with multiple parallel ridges and pockmarked with irregular depressions (see Figure 4). This Puget Lowlands topography is shaped by glacial and non-glacial processes (Haugerud 2009). The glaciers eroded and deposited material with each advance and retreat. The last ice sheet retreated approximated 16,400 calculated years before present (Porter and Swanson 1998). Pleistocene continental glacial till is the primary geologic unit deposited in the upper basin. The lower basin and the project site itself are underlain by Pleistocene glacial drift (DNR Geology Portal 2022). Glacial till consists of clay, silt, sand, gravel, cobbles, and some boulders. Non-glacial deposits include alluvium and colluvium from fluvial and hillslope transport. Urbanization of the watersheds has increased runoff and sediment supply to the streams. General geology for Puget Sound Lowlands includes lots of landslides, and these landslides also add to the sediment supply. However, the low gradient present throughout the valley retards some of the sediment transport as it progresses toward Liberty Bay.

The tributary from the north (North Tributary) is wider with a lower slope than the tributary from the west (West Tributary). The North Tributary comes from a natural valley with less anthropogenic influences, while the West Tributary travels through residential neighborhoods (less porous surfaces, less seepage/infiltration, less vegetation to absorb water, etc.), thus leading to more runoff. This increase of runoff, in addition to the confinement of the stream caused by infrastructure, could have increased the rate of scour and slope failures, adding more sediment to the main reach.

The United States Department of Agriculture, Natural Resources Conservation Service Soil Survey (2022) indicates that the creek flows through Alderwood gravelly sandy loam and a small area of Kapowsin gravelly ashy loam is located at the northern end of the basin. Note that this is only a partial assessment of soils in the basin because there is no data available for the westernmost part of the basin (see Figure 5 for the soils map).

Additional geotechnical data has not been received from the WDOT Headquarters (HQ) Geotechnical Scoping lead as of the date of this report was prepared.

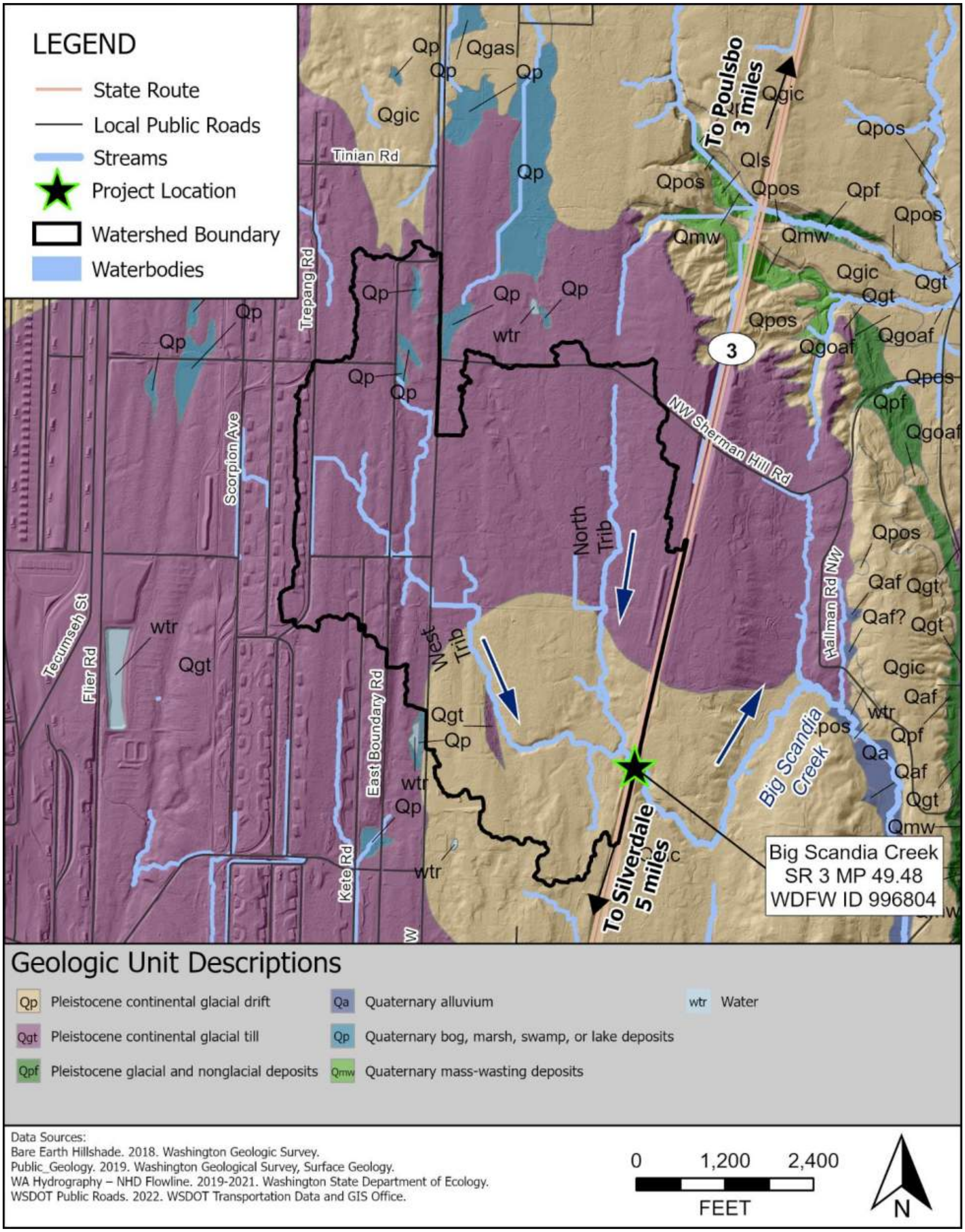


Figure 4: Geologic map

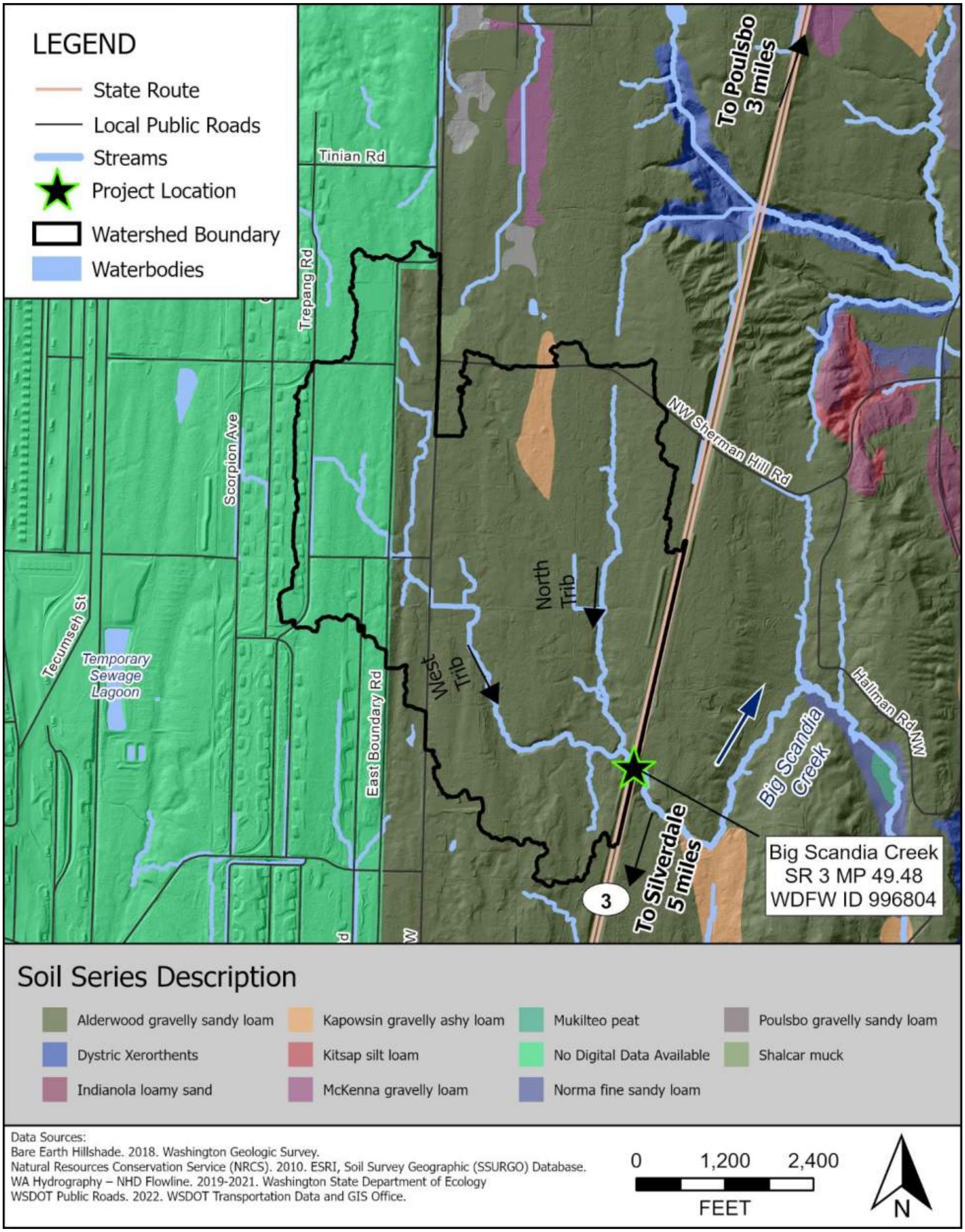


Figure 5: Soils map

2.4 Fish Presence in the Project Area

Table 2 provides a list of salmonid species documented and presumed to be found in Big Scandia Creek, a tributary to Liberty Bay in Puget Sound. Documented salmonids in the creek are coho (*Oncorhynchus kisutch)*, fall chum (*Oncorhynchus keta*), winter steelhead (*Oncorhynchus mykiss)*, coastal cutthroat trout (*Oncorhynchus Clarki clarki),* while resident trout *(Oncorhynchus mykiss)* are presumed to be within the creek (WDFW 2021). Information was gathered from the WDFW Fish Passage and Diversion Screening Inventory Database report (FPDSI, 2021) and the Statewide Washington Integrated Fish Distribution (SWIFD) dataset (WDFW 2021) managed by WDFW and the NW Indian Fisheries Commission.

Table 2: Native fish species potentially present within the project area

Species	Presence (presumed, modeled, or documented)	Data source	Endangered Species Act listing
Coho Salmon (*Oncorhynchus kisutch)*	Documented	SWIFD	Not Listed
Fall Chum Salmon (*Oncorhynchus keta*)	Documented	SWIFD	Not Listed
Winter Steelhead (*Oncorhynchus mykiss)*	Documented	SWIFD	Threatened
Coastal Cutthroat Trout (*Oncorhynchus Clarki clarki)*	Documented	SWIFD	Not Listed
Resident Trout (*Oncorhynchus mykiss*)	Presumed	SWIFD	Not Listed

2.5 Wildlife Connectivity

The 1-mile-long segment that Big Scandia Creek falls in ranked low priority for Ecological Stewardship and low priority for Wildlife-related Safety by WSDOT Headquarters (HQ) ESO. Adjacent segments to the north and south ranked medium. At the time this document was written, the habitat connectivity analysis was pending for this crossing.

2.6 Site Assessment

2.6.1 Data Collection

WSDOT provided a topographic survey of Big Scandia Creek from approximately 200 feet downstream of SR 3 to approximately 225 feet upstream (see Appendix D that was performed on September 9, 2021. David Evans and Associates, Inc. (DEA) visited the project site on December 1, 2021, to conduct a stream assessment and collect data needed to support development of preliminary design information. Flow in the creek was about 1 to 2 cubic feet per second (cfs) during the site visit. The existing crossing is a 203-foot-long, 54-inch-diameter corrugated steel culvert. The culvert is covered by about 30 feet of fill supporting SR 3. A large retaining wall supports the fill on the upstream side of the culvert crossing.

During the site visit and stream assessment, the DEA team observed local stream and drainage basin conditions in a reach that extends about 200 feet upstream of the culvert inlet and about 200 feet downstream of the culvert outlet. A summary of the site visit is provided in Appendix B provides a summary of DEA's site visit, and Figure 6 shows a plan view of the site. DEA measured eight bankfull widths (BFWs)—four upstream and four downstream of the crossing. Because the influence of the structure was less on the upstream section of the crossing than the downstream section where BFWs were measured, upstream cross-sections were expected to provide a better representation of the overall bankfull conditions for the stream. The average of the BFW for upstream cross-sections was 10 feet (see Section 2.7.2). DEA performed three pebble counts in the field—one upstream and two downstream of the crossing. The results of the downstream pebble counts (PC-1 and PC-2) were disregarded, because this section of the creek was determined to be impacted by the structure. Section 2.7.3 summarizes the results of the pebble counts.

WSDOT, WDFW staff, and Suquamish Tribal representatives visited the site on February 3, 2022. This site visit resulted in concurrence on the reference reach location and 10-foot BFW.

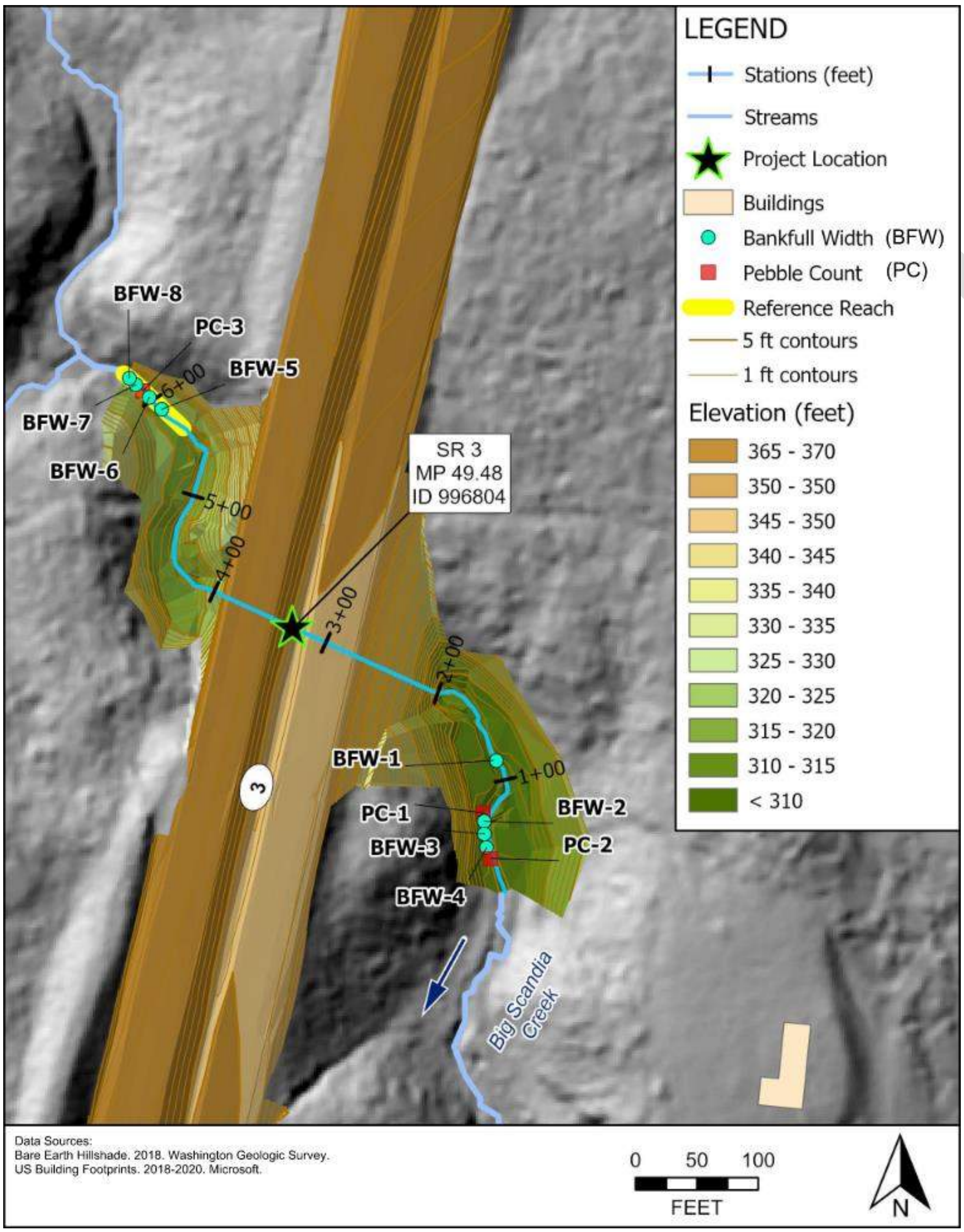
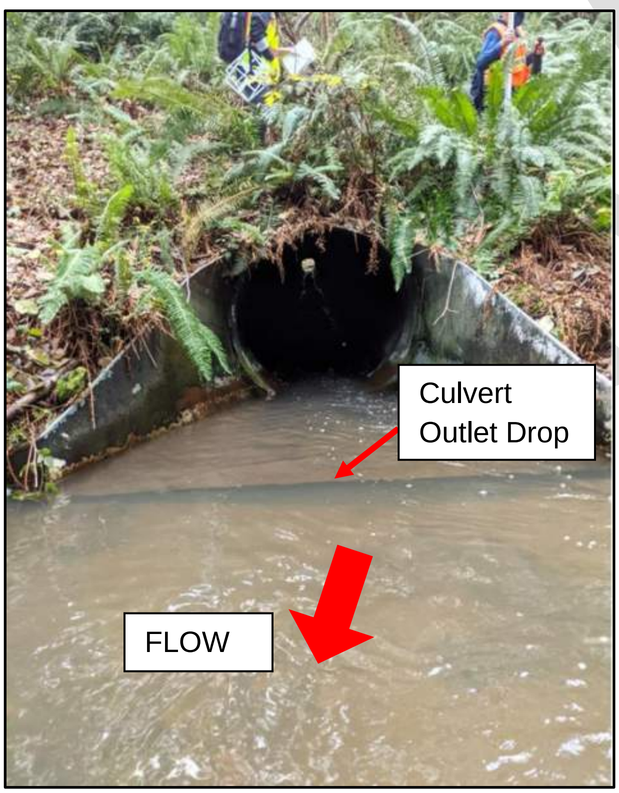


Figure 6: Reference reach, bankfull width, and pebble count locations

2.6.2 Existing Conditions

This crossing consists of one 54-inch round corrugated metal pipe (CMP) culvert that is 202.5 feet long (see Figure 7). The culvert inlet and outlet have metal flairs as wingwalls to support transition of flow through the culvert. The gradient of the culvert is about 1.5 percent, and it has a straight alignment through the highway fill. As-built information for the crossing was not available in the documents provided by WSDOT. This crossing has been identified by WDFW as a fish barrier due to water surface drop. The initial WDFW survey, conducted in 2004, shows that when the stream is dry there is a drop of about 0.8 foot caused by the metal flair that is part of the culvert structure (see Figure 7). During the DEA site visit, the stream had enough water to inundate this drop, so that the water surface level was equal on both sides. A pool was observed that has formed downstream of the drop (see Figure 7 and Figure 8). The turbidity observed in the stream could be a result of a recent storm in the area. High flows from the storm could have disturbed the fine sediments at the pool created by the drop and increased turbidity to the stream. Visual inspection indicates that the culvert appears to be in relatively good condition, with minor rusting along the invert (see Figure 9). There were no obvious signs of maintenance activity.

Four stormwater inlets are located on SR 3 within 150 feet of the existing crossing. The outlets from this stormwater conveyance discharge to roadside ditches, which in turn discharge to Big Scandia Creek. See the existing stream plan sheet Appendix D for locations of this infrastructure. None of these outfalls have an impact on the crossing. There is no other nearby infrastructure in the immediate vicinity.



Data Source: WDFW Fish Passage and Diversion Screening Inventory Database, August 4, 2004

Figure 7: Outlet of existing 54-inch CMP culvert with pool formed at the drop (approx. STA 2+00)

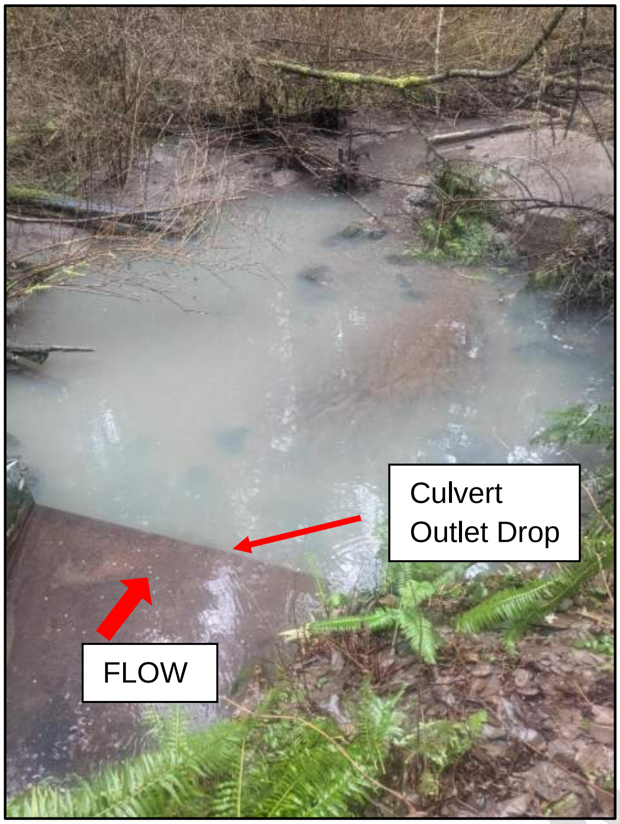


Figure 8: Outlet of existing culvert (approx. STA 2+00)

Figure 9: View of culvert upstream (approx. STA 4+00)

The stream assessment began near Station 6+30 at the upstream survey limits, approximately 250 feet upstream of the SR 3 crossing, and proceeded downstream. The stream assessment began here because upstream of this section there is a confluence of two tributaries of Big Scandia Creek from the west and north (see Figure 6). Above this point, the channel is in a different hydrologic regime. The West Tributary has a narrower valley upstream, and its flow is contained within the channel. The North Tributary has wider valley upstream, and its banks are also wider. In addition, the land cover draining into the West Tributary is more urbanized than the land cover draining the North Tributary.

Downstream of this confluence, the section of channel between approximately Station 6+30 and Station 5+60 was relatively undisturbed by the structural influence of the crossing, and it provided the best location for a reference reach. In this section, the left overbank is a filled hillslope from the highway, and the right bank is high, which confines the channel (see Figure 10 and Figure 11). The bank vegetation in this section is mostly mature cedars (*Cedrus*) and alder (*Alnus*) in the overstory, and salmonberry (*Rubus spectabilis*) and swordfern (*Polystichum munitum*) in the understory cover. There are a few pieces of large woody material (LWM) as well as some small wood present in the reference reach (see Figure 11). Section 2.7.1 presents a further explanation of channel geometry and vegetation for the reference reach.

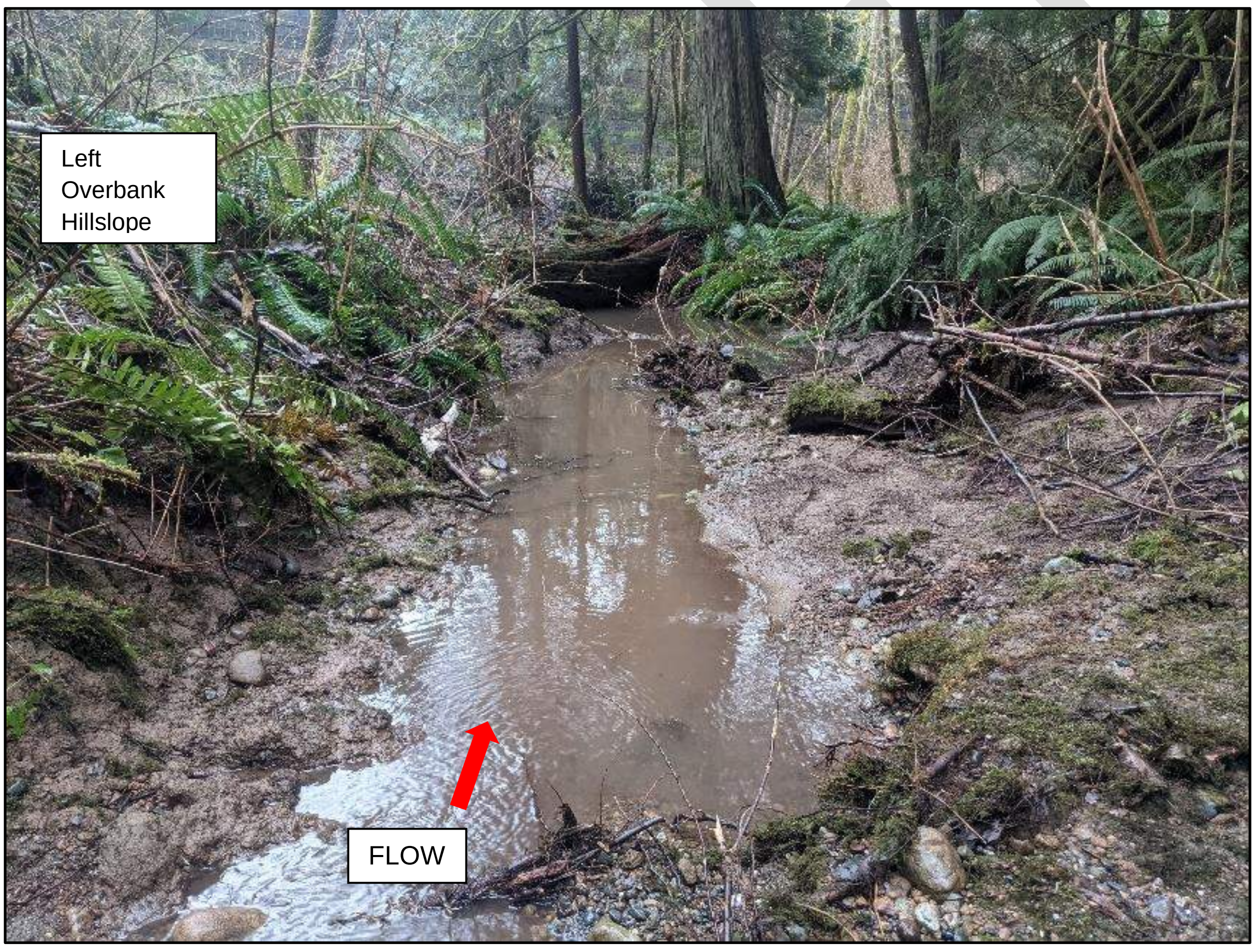


Figure 10: View of reference reach (approx. STA 6+30)

Figure 11: Reference reach upstream of SR 3 (some LWM present on the stream) (approx. STA 5+75)

The channel downstream of the reference reach, between approximately Station 5+60 to Station 4+90, was shallow, and the channel slopes were approximately 1.3 percent. The left overbank is a relatively steep hillslope, which could be a result from the fill of road embankment and this section is where the stream bends to the south-west (see Figure 12). The bend causes the channel to lose some energy and with reduced velocities, aggradation of fine materials and organic matter in the streambed can be observed (see Figure 13). These low energy flows could be attributed to the presence of the culvert, which is preventing the channel from attaining a natural flow regime. In this section, a few tree logs were present that were less than 12 inches in diameter (see Figure 14). The vegetation along this section is cedar, red alder, salmonberry, and swordfern. This vegetation provides some shade, but tree canopy cover is limited in this section.

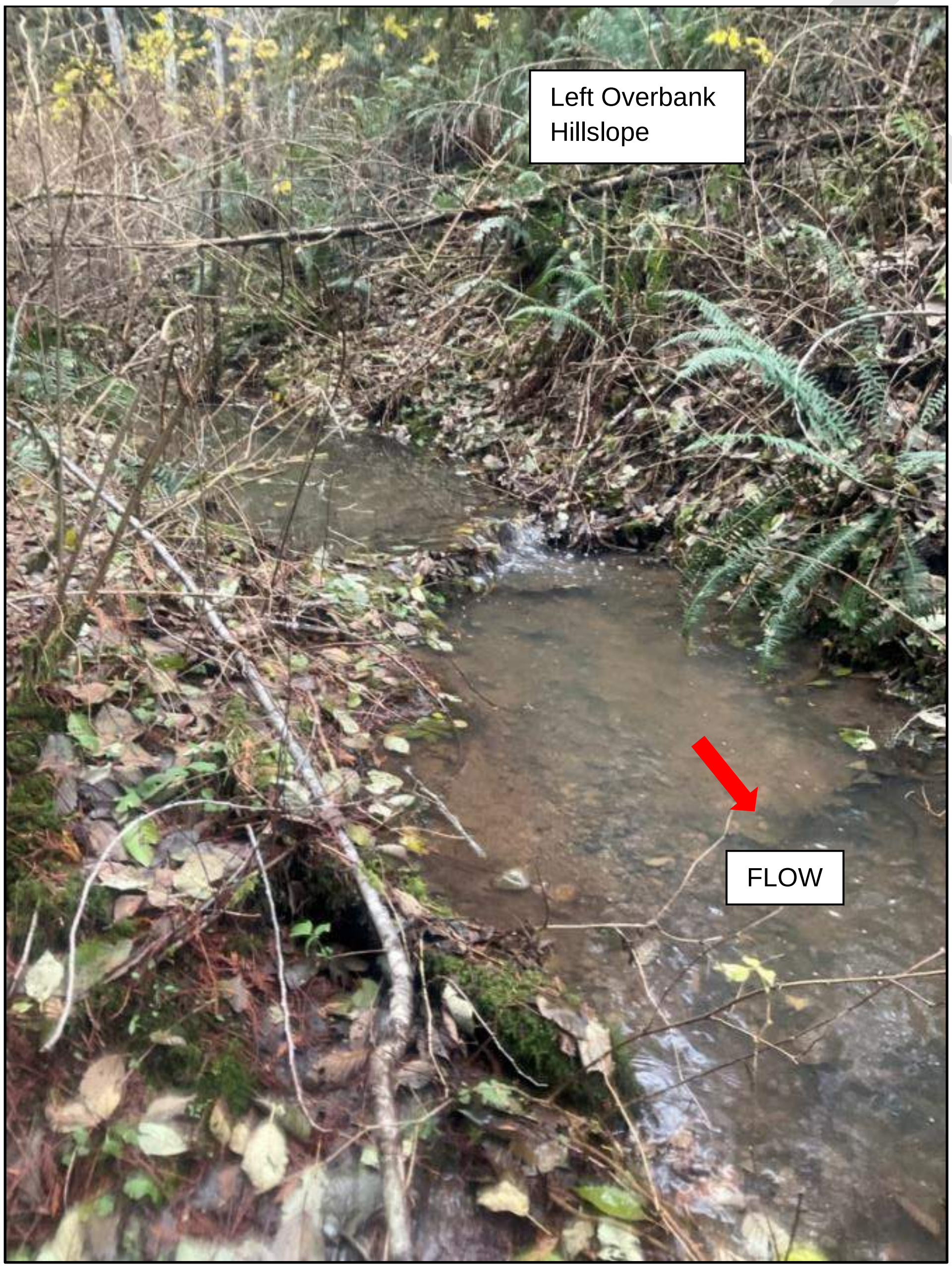


Figure 12: View of channel near STA 5+00

Figure 13: Aggradation of fine sediment and organic matter near STA 5+40

Figure 14: Woody material at the left overbank and tree logs near STA 5+30

Farther downstream, approximately between Station 4+90 to Station 4+30, the channel has a slope of about 1.3 percent. The stream has another bend at this section to the south-east direction and due to this bend some energy is lost which causes lower velocities. There is presence of some woody material along the channel (see Figure 15). The vegetation in this section is still mostly salmonberry and ferns along the banks, while red alder is the prominent overstory vegetation. There are some woody materials present along the section (see Figure 16). Although the stream is mostly confined, flows in the channel at some locations in this section might have limited access to the overbanks during high flows (see Figure 16 and Figure 17).

Figure 15: Woody material near STA 4+50

Figure 16: Woody material and channel bed material near STA 4+30

Figure 17: Channel section near STA 4+50

The section of channel approximately between Station 4+30 and Station 3+90 is immediately upstream of the culvert inlet. The slope was similar to upstream section of about 1.3 percent. Behind the culvert inlet, a large 30-foot retaining wall supports the SR 3 road fill (see Figure 18). The channel banks are not prominent along this section, and there is some LWM along with woody material (see Figure 19 and Figure 20).

Figure 18: Wall with large fill height (approx. 30 feet) at the upstream side (approx. STA 4+00)

Figure 19: Woody material and bed material along the channel upstream of the culvert (approx. STA 4+10)

Figure 20: Woody material and bed material near STA 4+20

The section of channel immediately downstream of the culvert approximately between Station 2+00 and Station 1+70 has a slope of about 0.9 percent. This section has the channel drop of 0.8 feet which causes this crossing to be a barrier for fish passage. Overall, on the downstream section, along the channel length, clusters of woody material cause small periodic drops of less than a foot at multiple locations (see Figure 21 and Figure 22). These drops, which were observed during the site visit on December 1, 2021, were swept away by a larger flood event and were not present on the subsequent site visit on February 3, 2022, as shown on Figure 22.

Downstream of this section, approximately between Station 1+70 and Station 0+00, the channel is overall confined (see Figure 23) and has flat overbanks. The right overbank is on private property delineated by wire fences (see Figure 24). This section also has some smaller woody material that is less than 12 inches in diameter. The vegetation in this section mainly consists of fern cover on the banks and salmonberry and some alder trees in the overstory. At some spots in this section, the channel has been partially blocked by woody material (see Figure 21), which has caused some local aggradation and loss of channel definition. At some spots, this aggradation could cause the left overbank of the channel to be accessible to high flows until the woody material is swept away, as was observed during the site visit on February 3, 2022. On the right side, a fill hillslope is present (Figure 6), which makes it inaccessible to overbank flows even at high flows, as shown on Figure 25. The stream assessment ended at Station 0+00, about 200 feet downstream of the culvert outlet.

The better existing habitat for fish lies primarily upstream of the culvert. The presence of two tributaries, LWM, pools, and adequate canopy cover provide juvenile coho, steelhead, and trout salmonids with adequate rearing habitat. The low energy nature of the creek does not, however, provide any spawning potential in the immediate reaches upstream of the culvert. Downstream of the culvert, there is little habitat for adult or juvenile salmonids. Minimal overstory canopy, shallow and wide channels, and an abundance of organic and fine material limit the opportunity for juvenile salmonids to find adequate space for rearing. Adult salmonids find no spawning gravels here and will use this section of the creek only to access higher quality habitat upstream.

Figure 21: Drops created by small woody material near STA 1+40

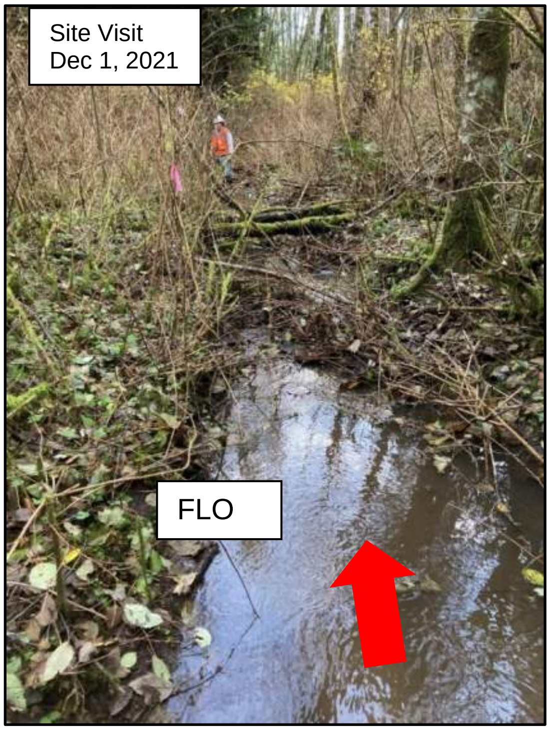


Figure 22: Flow downstream of the culvert across confined sections, with small woody material at some sections (approx. STA 1+70) that is shifted by larger flood events (site visit Feb 3, 2022)

Figure 23: Confined channel section downstream of the culvert, with private property on the right side of the fence (approx. STA 0+70)

Figure 24: Woody material and vegetation near STA 0+90

Figure 25: View of downstream channel showing that the right overbank is a hillslope that cannot be accessed by high flows (approx. Sta 0+50)

2.6.3 Fish Habitat Character and Quality

The SR 3 culvert for Big Scandia Creek is classified as 33 percent passable because of the water surface drop (FPDSI 2021). Documented salmonids within Big Scandia Creek are coho salmon, fall chum salmon, winter steelhead, and coastal cutthroat trout. Resident trout are presumed to be within the creek.

Upstream of the culvert, creek habitat has been impacted by reduced velocities as the reach is influenced by the culvert, providing very little habitat for both juvenile and adult salmonids. The area near the culvert features a shallow, wide, and slow-flowing section of the creek, and provides little benefit to juvenile salmonids, because there are no pools, LWM, or canopy cover present to provide shelter. The substrate is composed primarily of organic material, sand, and fines, which is poor spawning habitat.

Approximately 100 feet upstream of the culvert inlet, riparian habitat returns to a more natural state, and fish habitat improves. The channel becomes more defined, spawning gravels are present, and LWM becomes more abundant. The West Tributary of Big Scandia Creek enters from around 250 feet upstream of the culvert, on the right bank, and features similar habitat characteristics to Big Scandia Creek. This area of the creek provides benefit to juvenile salmonids with rearing habitat. Spawning habitat in this section is present but could be improved, because the substrate is composed primarily of sand and fines.

Downstream of the culvert, spawning and rearing habitat is absent. Dense salmonberry does provide the stream with cover, but it also has created a buffer between the stream and mature trees, opening the canopy and adding large amounts of smaller woody material. The presence of this accumulated small wood creates flow obstructions and a substantial floodplain shelf, thus spreading the stream out, without much of a defined streambed. As a result, high quantities of organic material, sand, and fine particulates make up the majority of the streambed and give little value to salmonids of any kind. The plunge pool was the only observed pool within the downstream reach at the culvert outlet (at Station 2+00), and no LWM or other features that would enhance rearing habitat were observed. No spawning habitat is present in this downstream stretch of the creek.

No wetlands were observed on either side of the culvert.

2.6.4 Riparian Conditions, Large Wood, and Other Habitat Features

In the reference reach, where the overbank consists of cedars with fern groundcover, the channel is well-defined and has deep pools with overhanging vegetation. However, the channel in the reference reach is clear of wood material that would provide additional habitat enhancement. The lack of LWM has reduced the channel resiliency to aquatic life and could have caused habitat issues such as lack of cover from predators, reduced macroinvertebrate habitat, and lack of shade and refuge, as well as bank erosion. Future recruitment of LWM to the reach is possible given the presence of overstory trees. Branches and fallen trees both have the ability to end up in the stream. One cedar tree was observed that was leaning over the stream and will eventually contribute LWM to the stream, while other alder and cedar trees grow nearby and have the potential to contribute LWM over time.

Outside of the reference reach, the overbank vegetation consisted of salmonberry and red alder, species that readily establish in disturbed areas where there is full to partial sunlight. In these locations, the channel is narrow and shallow, and appeared to be choked with small woody material, leaves, and other organic matter. The vegetation is dense but only results in partial shade, and the shallow water levels, low flow, and organic matter can lead to high temperatures and low oxygen levels. The site visits did not reveal the presence of any noxious weeds.

There is no indication that beaver activity is present on the site.

2.7 Geomorphology

Geomorphic information provided for this site includes selection of a reference reach, the geometry and cross sections of the channel, and stability of the channel both vertically and laterally of Big Scandia Creek.

2.7.1 Reference Reach Selection

The reference reach is a 70-foot long segment that begins approximately 235 feet upstream of culvert inlet and extends to approximately 165 feet upstream of culvert inlet (Station 5+60 to 6+30) (see Figure 6). This section of the reach did not appear to be directly influenced by the structure. The average stream gradient within the reference reach did not show significant changes between reaches upstream and downstream. There were no signs of chronic erosion or deposition, and there were no human-made features close to the reach. The sediment size distribution also did not appear to change significantly upstream and downstream of the reach. Therefore, this reach was assumed to represent the background (natural) condition of the project reach and was selected as reference reach. Within the reference reach, the overbank vegetation consists of mature cedars and hemlock trees; a ground cover of salmonberry and swordferns; and a deeper, shaded, and well-defined channel (see Figure 26) that provides better habitat than was present elsewhere in the reach.

The section of stream upstream of the reference reach is at the confluence of two tributaries to the creek, and the flow regime of each tributary is different and not representative of Big Scandia Creek at the project reach. The flow pattern in the section immediately downstream of the selected reference reach is affected by the channel bend, where some energy is lost which causes lower velocities and deposition. This can be seen with presence of higher amounts of fines. This can be observed with presence of higher amounts of fines. Downstream of this bend, a small section of the channel constricts and has slightly higher velocities.

The channel morphology downstream of the reference reach appears to be influenced by vegetation that consists of red alder and salmonberry, resulting in a shallow channel with a channel bed consisting of fine material and organic matter (see Figure 27). Red alder and salmonberry are common in areas that have undergone disturbance that creates high light conditions; therefore, this vegetation is likely present due to the ground disturbance created during construction of the highway. The reference reach was selected as a location where the vegetation transitions to include mature cedars and ferns and where the channel is better defined.

Survey of the reference reach indicates that the channel slope in the reference reach is approximately 1.3 percent. The stream assessment included BFW measurements in four places (see Section 2.7.2) to characterize the reference reach. Based on these measurements, the average BFW is 10 feet. One pebble count taken in the reference reach (as discussed in Section 2.7.3) measured the sediment distribution.

During a site visit on February 3, 2022, WDFW and the Suquamish Tribe concurred with the location of the reference reach.

Figure 26: Reference reach selection representative of background conditions (photo: looking downstream)

Figure 27: Upstream of culvert looking towards culvert inlet and highway

2.7.2 Channel Geometry

The channel has a slight meander and a low-gradient plane-bed planform geometry contained within the benches of the hillslope. Flow overtops the stream banks during high-flow events, but remains limited to the overbank areas within 10 to 20 feet of the stream banks. There are no visible floodplains beyond the immediate overbank area. See Section 2.7.2.1 for details about the flood-prone widths of Big Scandia Creek.

The cross-sectional geometry adjacent to culvert openings is not as well-defined as it is farther away (upstream or downstream) from the culvert opening, thus indicating the effect of structure on channel geometry. The channel slope at the reference reach is about 1.3 percent. This slope is matched by the proposed design at 1.3 percent through the reconstructed reach. The observed reaches directly upstream and downstream of the culvert (see Figure 6) are at a longitudinal slope of 1.3 percent and 0.9 percent, respectively. The combination of mild slope, observed fine bed material, and the lack of erosional features indicates low energy flow conditions.

Four BFW measurements were obtained in the reference reach (see Figure 28, Figure 29, Figure 30, and Figure 31). Bankfull elevation was identified by the lack of vegetation or by an inflection point in the slope. The water depth ranged from 0.5 foot to 1.5 feet in the reference reach at the time of the site visit. As seen in the figures, the water depths measured were lower than the depths for bankfull events. In the reference reach, the bank heights ranged from 1.0 foot to 2.5 feet, and the bank slopes were steep, ranging from 1:2.5 to 1:3 (Horizontal:Vertical).

There is a clear difference in channel geometry downstream of the reference reach. The BFW measurements downstream of the culvert indicated that the channel was narrower and ranged from 6 feet to 7.5 feet (see Figure 32 and Figure 33). The channel is shallow, generally less than 6 inches deep. It can be expected that at some of these sections, bank full flow will overtop the banks and utilize overbanks. The channel bed consists of fine sediment and organic matter that was easily displaced when stepped on. This sediment causes a smooth transition between the channel and the overbank. Pockets of coarser sand with some gravels were observed near the existing water level, indicating that they were transported and deposited during high flow events.

Based on the channel geometry, the stream seems to be stable in nature, because the banks have been developed with no clear indications of erosion. However, fallen and tilting trees observed along the stream banks indicate some lateral migration. With the water surface drop pool at the downstream end of the culvert, the downstream section has shallower channel depth and seems to have a slightly wider floodplain than the upstream section. The average width-to-depth ratio is around 7.6 but it increases to nearly 10.0 at certain locations. The width-to-depth ratio is an indicator of habitat quality and relatively deep, narrow streams provide better fish habitat than shallow wider channels. Although the existing conditions indicate that the banks downstream are low, it is expected that after the proposed structure is built (and when the flow regime of adjacent downstream and upstream reaches of the culvert are similar), the downstream section of the stream might evolve to have a deeper and more confined channel, as seen in the upstream section and the reference reach.

Figure 28: BFW-5 measurement of 8 feet, measured within the reference reach approximately 180 feet upstream of the culvert

Figure 29: BFW-6 measurement of 12 feet, measured within the reference reach approximately 200 feet upstream of the culvert

Figure 30: BFW-7 measurement of 12 feet, measured within the reference reach approximately 210 feet upstream of the culvert

Figure 31: BFW-8 measurement of 8 feet, measured within the reference reach approximately 220 feet upstream of the culvert

Figure 32: BFW-1 measurement of 6 feet, measured outside of the reference reach approximately 100 feet downstream of the culvert

Figure 33: BFW-3 measurement of 7.5 feet, measured outside of the reference reach approximately 170 feet downstream of the culvert

BFWs are summarized in Table 3; BFWs range between 8 feet and 12 feet in the reference reach and range between 6 feet and 7.5 feet outside of the reference reach. Figure 34 shows the comparison of channel geometry for the locations where BFWs were measured within the reference reach. The figure shows some differences in the BFW as measured in the surveyed topographic surface versus as measured in the field. The inflection points are not as clear at some locations and the exact locations of measurements are sometimes not easy to ascertain. However, the average BFW of 10 feet seemed to characterize the reference reach geometry well. The project team discussed the measured BFWs and hydraulic opening with WDFW staff and Suquamish Tribe representatives during the site visit on February 3, 2022. An average BFW of 10 feet was agreed upon. This agreed-upon BFW will be used to inform the width of the structure opening based on the stream simulation method. Design team engineers can discuss with WSDOT and stakeholders to increasing this width for design purposes if needed.

Table 3: Bankfull width measurements

BFW number	Width (feet)	Included in design average?	Location measured (distance from culvert)	Concurrence notes
BFW-1	6	No	100 feet downstream	
BFW-2	7.5	No	140 feet downstream	
BFW-3	7.5	No	155 feet downstream	
BFW-4	7.5	No	170 feet downstream	
BFW-5	8	Yes	180 feet upstream	Stakeholder concurred on 2/3/2022
BFW-6	12	Yes	200 feet upstream	Stakeholder concurred on 2/3/2022
BFW-7	12	Yes	210 feet upstream	Stakeholder concurred on 2/3/2022
BFW-8	8	Yes	220 feet upstream	Stakeholder concurred on 2/3/2022
Design average	**10**			Stakeholder concurred on 2/3/2022

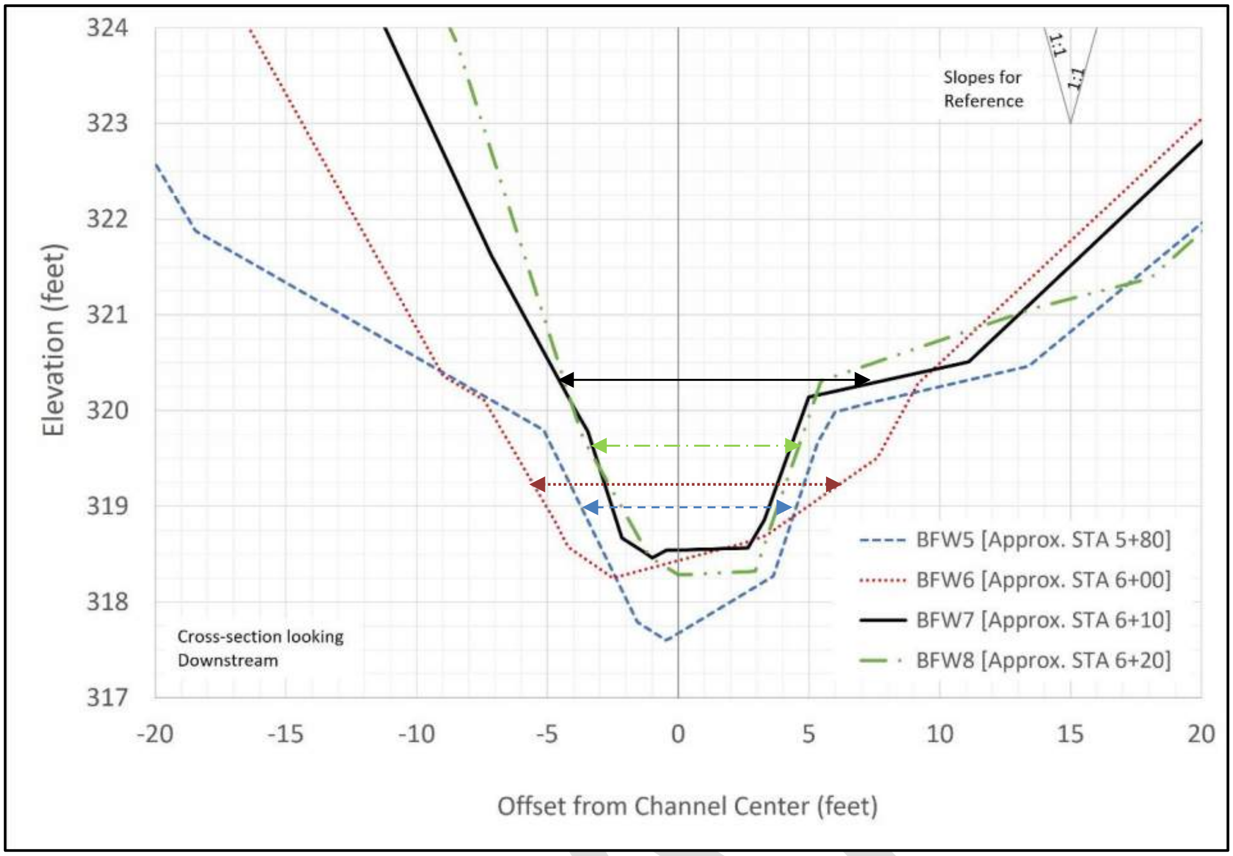


Figure 34: Existing cross-section at the four BFW locations within the reference reach

2.7.2.1 Floodplain Utilization Ratio

Floodplain Utilization Ratio (FUR) is the ratio of flood prone width divided by the bankfull width which gives an indication of how entrenched the channel is. The project team determined the flood-prone width (FPW) of Big Scandia Creek by measuring the FPW at various representative locations upstream and downstream of the crossing. FPW measurements were taken from the existing conditions SRH-2D model during the 100-year flow event and average BFW measurement was taken from Table 3 and measurement from topographical survey data. Figure 35 shows and Table 4 lists the location of each FPW measurement. The upstream FPW measurements were made by artificially expanding the existing 4.5-foot culvert to a 10-foot culvert to avoid backwater conditions. The floodplain utilization ratio (FUR) along the reference reach and locations where the effect of the structure is negligible. The drop barrier was still present in this model, which does not represent a natural condition of the stream. Therefore, any measurement of FUR downstream of this drop section was not included in the FUR calculation. The resulting average FUR is 2.5 and the channel considered to be confined as specified by WCDG (Barnard et. al., 2013).

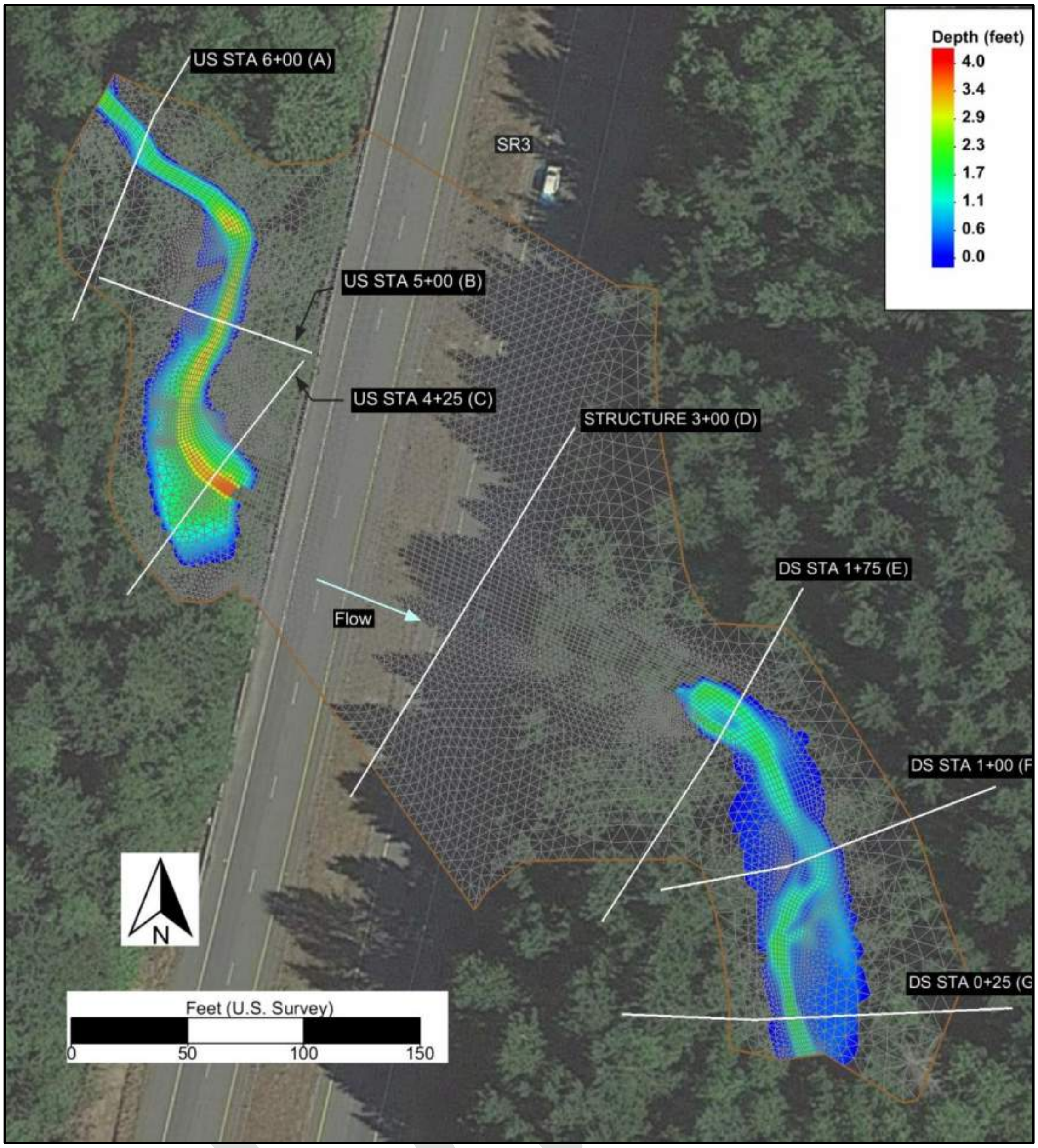


Figure 35: FUR locations with 100-year flow depths

Table 4: FUR determination

Station	FPW (feet)	BFW (feet)	FUR	Confined/ unconfined	Included in average FUR determination
Upstream STA 6+00 (Reference Reach)	17.1	10	1.7	Confined	Yes
Upstream STA 5+00	18.5	10	1.9	Confined	Yes
Upstream STA 4+25	47.5	10	4.8	Unconfined	Yes
Downstream STA 1+75	24.9	10	2.5	Confined	No.
Downstream STA 1+00	40.3	10	4.0	Unconfined	No
Downstream STA 0+25	40.1	10	4.0	Unconfined	No
Average	**31.4**	**10**	**2.5**	Confined	Yes

2.7.3 Sediment

DEA conducted three Wolman pebble counts at the site. See Figure 6 for pebble count locations. The channel bed consisted of sand with pebbles and gravels in the reference reach; and the sediment distribution was captured at the pebble count location PC-3. Most of the channel downstream of the reference reach consisted of fines and organic matter, but there were two observed local areas with sands and gravels that could be characterized with a pebble count. PC-1 was along a length of stream approximately 135 feet downstream of the existing culvert outlet, and PC-2 was along the length of stream approximately 150 feet downstream of the existing culvert outlet. Because of the limited size of the sand and gravel deposits, these two pebble counts consisted of 20 to 25 samples each to avoid oversampling the small area. Therefore, the two pebble counts represent about 20 percent of the total reach, and the remaining parts of the reach are fines. See Figure 36 for approximate sediment dimensions and distribution at the location of PC-1. See Figure 37 for approximate sediment dimensions and distributions at the location of PC-2. These pebble counts represent the coarser material that is present and is transported through the reach during high flows and deposited.

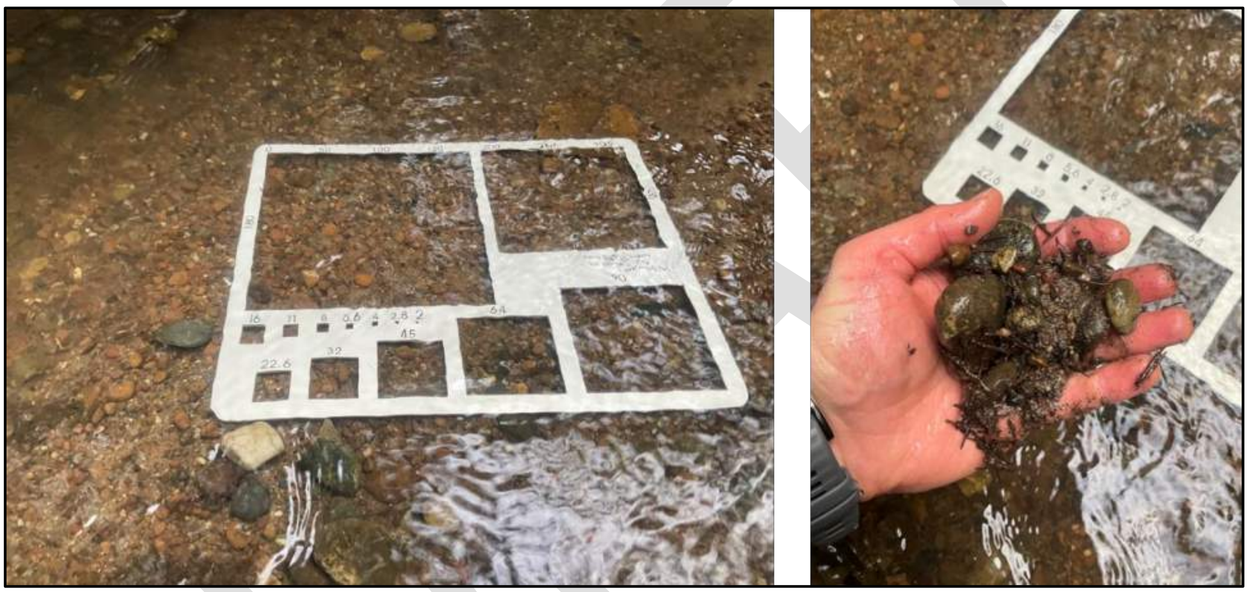


Figure 36: PC-1 sediment with gravelometer (left) and in hand (right)

Figure 37: PC-2 sediment with gravelometer (left) and in hand (right)

PC-3 was along the length of stream approximately 240 feet upstream of the existing culvert inlet within the reference reach. The sediment here consisted generally of sandy sediments with some coarser materials. See Figure 38 for approximate sediment dimensions and distributions at the location of PC-3. Table 5 lists and Figure 39 shows the results of the pebble counts.

Figure 38: PC-3 sediment with gravelometer (left) and in hand (right)

Table 5: Sediment properties near the project crossing

Particle size	Pebble Count 1 diameter (inches)	Pebble Count 2 diameter (inches)	Pebble Count 3 diameter (inches)	Average diameter for design (inches)
Included in average?	No	No	Yes	
$\mathbf{D_{16}}$	0.003	0.003	0.003	0.003
$\mathbf{D_{50}}$	0.26	0.36	0.29	0.29
$\mathbf{D_{84}}$	1.0	0.71	1.12	1.12
$\mathbf{D_{95}}$	1.5	0.86	1.75	1.75
$\mathbf{D_{100}}$	1.7	1.77	5.04	5.04

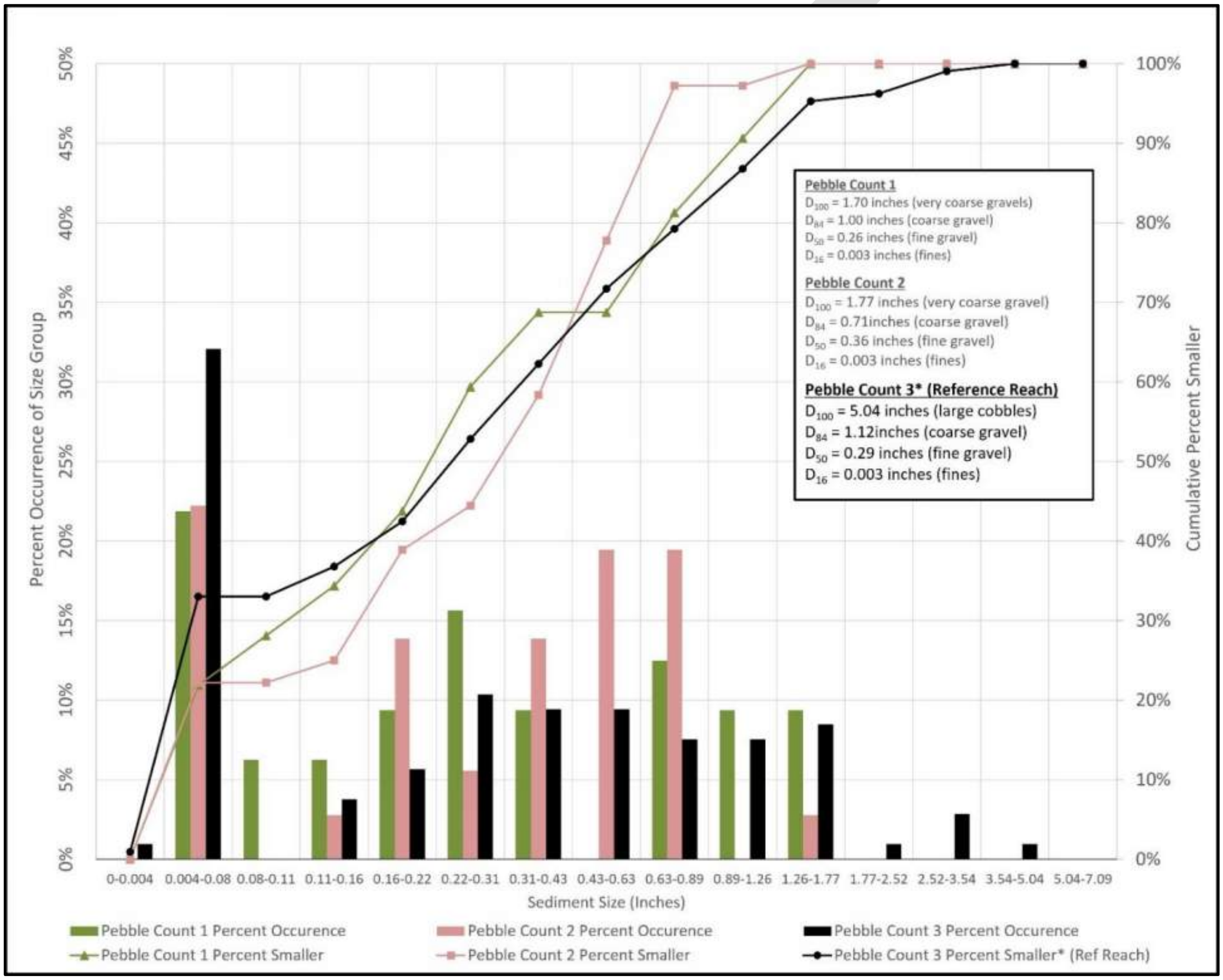


Figure 39: Sediment size distribution

2.7.4 Vertical Channel Stability

No active vertical incision was observed in the visited reach upstream and downstream of the culvert. There was a deeper pool at the culvert outlet that was caused by the local hydraulic conditions and does not occur elsewhere in the reach (see Figure 40). The channel downstream of the culvert has been aggraded with fine sediment and organic matter with woody material present to create periodic flow obstructions that have drops of 1 inch to 2 inches (see Figure 41). These flow obstructions typically wash out during 2-year flow events, preventing the development of permanent grade control features. The low gradient of the channel does not provide enough energy to move sediment load, thus causing deposition that makes the stream transport-limited. Sediment supply is expected to originate more from the West Tributary of the stream than the North Tributary, because the urbanized parts of the watershed generate more runoff as well as higher velocity of flow. This increased runoff and higher flow velocity can cause scour of streambed materials, thus increasing sediments to the main reach.

The overbanks are accessible at some locations where high flows could spread out into the overbank. However, most of the channel sections are confined, and the energy is expected to be contained within the main channel. The long profile, which was developed using topographic survey data and LIDAR (outside the extents of topographical survey limits), does not indicate the presence of a grade break between the upstream and downstream sides of the culvert, so a long-term channel regrade is not anticipated at this site. There is some potential for long-term aggradation in a localized area upstream of the channel (at approximately Station 10+00 in Figure 40) due to differences in longitudinal slope between reference reach and the reach immediately upstream of the channel. Additionally, this change in slope could have deposited some coarser sediments along the reference reach. See Section 7.2 for further details.

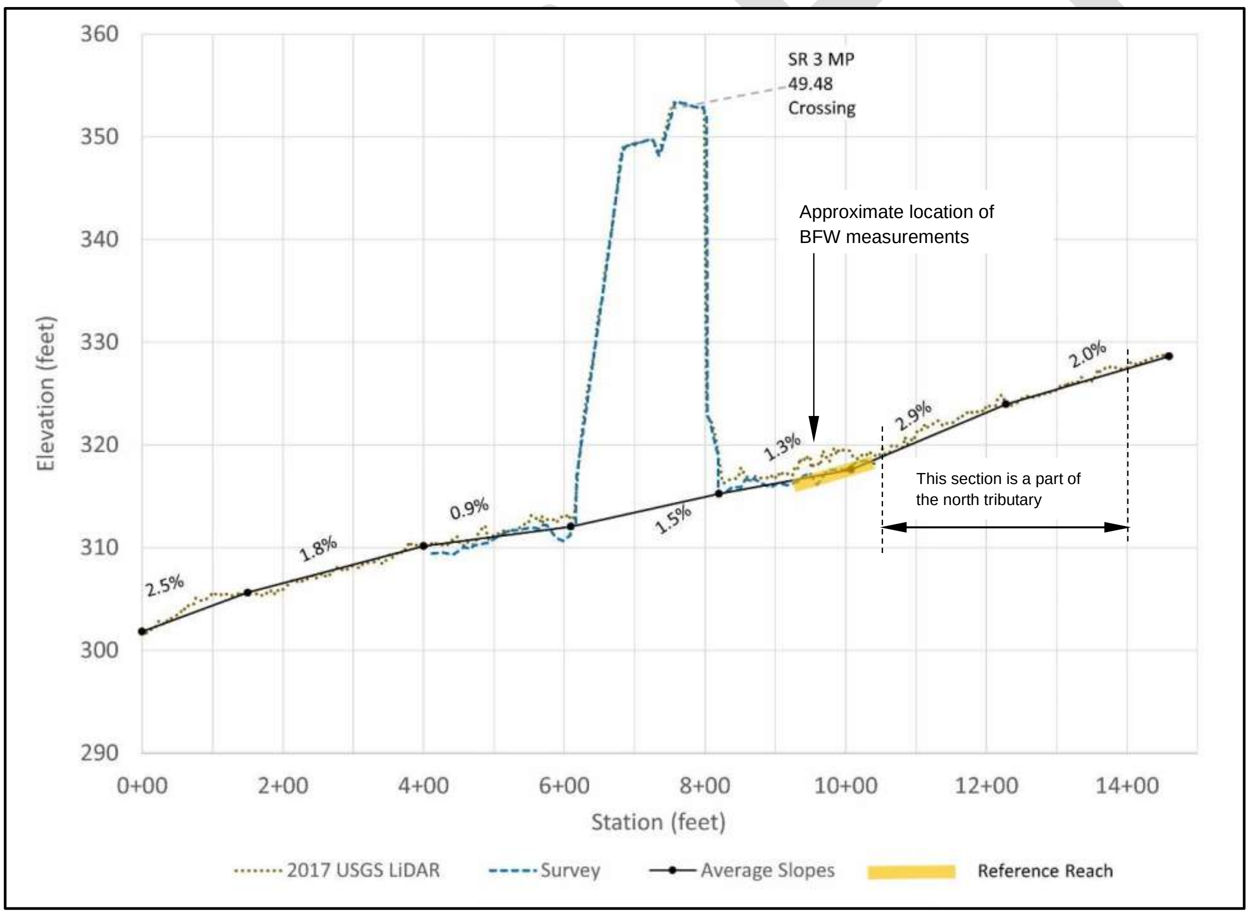


Figure 40: Watershed-scale longitudinal profile

Figure 41: Typical flow obstruction from woody material

2.7.5 Channel Migration

No evidence of recent lateral erosion was observed in the field nor was longer-term channel migration observed in the field or from review of the LiDAR topography. The likeliest mechanism for a change in the channel form would be tree falls obstructing the channel and creating local adjustments; however, no LWM was observed in the channel during the December 2, 2021, site visit. However, some stream-adjacent trees had fallen during a storm event before the February 5, 2022, site visit. There was a large butt log, approximately 10 feet tall, that was leaning towards the channel at the downstream end of the reference reach (visible in Figure 30) that was in an advanced state of decay (see Figure 42) and has likely been in that position for many years. This condition of this log indicates long-term stability at the downstream section of the reference reach.

In the existing conditions, the culvert restricts free flow, as evidenced by the pooling upstream of the culvert. This restriction of free flow might have reduced energy in the flow within the channel upstream of the culvert, which also reduces incision. This reduction of energy causes some lateral movement of the channel but the hillslope on both sides restricts large significant lateral movements. However, when a new structure that allows free flow is installed, this limited lateral movement would also be reduced.

In the downstream end, the water surface drop pool downstream of the culvert outlet slows flow velocity. This slower flow velocity might be the reason for this downstream end of the reach having a comparatively shallower and wider channel than the upstream reach. With a new structure that allows for flow to freely pass within the culvert, the channel downstream might initially widen the currently low-gradient banks; however, eventually the channel downstream is expected to behave similarly to the reference reach and to have more defined banks. So, channel migration is less likely to occur in the long term after the proposed structure is put in place.

Figure 42: Decay of butt log, approximately 10 feet long, leaning into channel at downstream end of reference reach

3 Hydrology and Peak Flow Estimates

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges and buried structures through a risk-based assessment beyond the design criteria. The largest risk to bridges and buried structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and to maintain passability for all expected life stages and species in a system.

There are no streamflow gages located on Big Scandia Creek, and no stream gages on similarly sized streams nearby. The USGS web app StreamStats (USGS 2016) provides a reasonable estimate of flow quantities because the mapped streamlines in the app are representative of the actual channel location. In addition, the hydraulic model tested the 2-year flows from StreamStats, and they resulted in depth of flow with widths consistent with the measured BFWs. MGSFlood was also used to estimate flow for different recurrence intervals. The 2-year flows from MGSFlood are the same as the 2-year flows from USGS StreamStats. Therefore, the flows from USGS Streamstats were selected as the approximation of typical flows for the channel for design. Table 6 provides peak flows for selected recurrence intervals for the creek.

WSDOT evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. All sites consider the projected 2080 percent increase throughout the design of the structure. Appendix G contains the projected increase information for the project site. The design flow for the crossing is 69 cubic feet per second (cfs) at the 100-year storm event. The projected increase for the 2080 100-year flow is 62 percent, yielding a projected 2080 100-year flow of 112 cfs.

Table 6: Peak flows for Big Scandia Creek at SR 3

Mean recurrence interval (years)	USGS regression equation (Region 3) (cfs)	MGSFlood (cfs)
2	**21**	21
10	**41**	54
25	**52**	78
50	**60**	101
100	**69**	114
500	**90**	125
Projected 2080 100-year flow	**112**	185

4 Water Crossing Design

This section describes the water crossing design for SR 3 MP 49.48 Big Scandia Creek, including channel design, minimum hydraulic opening, and streambed design.

4.1 Channel Design

This section describes the channel design developed for SR 3 MP 49.48 Big Scandia Creek. The proposed design uses one typical cross-section shape that is implemented over 313 feet of channel grading with a grade of 1.3 percent.

The main objective of the channel design is to remove the fish passage barrier, identified as water surface drop, that exists downstream of the culvert. The design process supports the replacement of the existing structure by an appropriate hydraulic structure that can simulate the natural processes that support fish passage, as observed in reference reach. This design process also attempts to simulate natural flow transitions from adjacent reaches to and from the proposed structure. Design for simulation of natural processes to support fish passage includes design of channel shape, planform, alignment, and gradient.

The design of channel shape uses the average measured BFWs within the reference reach. The design also includes grading of the channel section to seamlessly transition to the existing channel and thereby to provide adequate depth and flow velocity for fish passage. The channel cross-section does not have variability along the proposed alignment. The stream assessment determined the targeted channel slope to be 1.3 precent by comparing the slope of the existing structure to the slopes of adjacent reaches. This slope does not vary within the proposed section. The design would preserve the existing channel alignment for the proposed section based on the site constraints of the existing roadway embankment. No major variability is proposed in channel cross-section and alignment throughout the proposed channel section.

4.1.1 Channel Planform and Shape

The WCDG (Barnard et al. 2013) recommends that a proposed stream channel have a gradient, cross-section, and general configuration that are similar to the existing channel upstream and downstream of the proposed crossing, provided that the adjacent channel has not been modified in a way that adversely affects natural stream processes. The site visit evaluated existing conditions for Big Scandia Creek both upstream and downstream of the SR 3 crossing (see Section 2).

Much of the channel hydraulic properties such as flow depth, velocities, and bed shear stress depend on the shape of the channel cross-section. Therefore, the proposed channel shape is designed to mimic the existing sections observed in the reference reach and measured from survey data. In the reference reach, the bank heights ranged from 1.0 foot to 2.5 feet, and bank slopes ranged from 2.5:1 to 3:1 (H:V). Observed channel banks at the project site were relatively stable and did not have much aggradation or degradation at the reference reach, so these channel geometries were used to determine proposed channel cross-section including bank slopes. Using the existing bank slopes in determining the proposed design will support creation of flow regimes at the proposed section that will continue the same channel processes seen in the reference reach through the crossing. The cross-slope of the proposed channel bed was also estimated using the reference reach channel shape to ensure that sediment transport remains steady and representative of the existing reference reach. Using the channel shape of the reference reach as a template for proposed channel bed cross-slope also ensures that the proposed channel section will not have undesired incision of the channel bed or aggradation of sediments on the bed. Designing the proposed channel section based on bank heights and widths from the reference reach means that flow depths and velocities for fish passage as well as habitat will be close to natural conditions during low or high flows. A channel that is too wide can result in lower flow depth during low-flow periods, and narrow sections can result in higher velocities than natural conditions of the channel, which would in turn adversely affect fish passage and habitat. The channel, which has a plane-bed morphology, is intended to provide adequate depth and flow velocities, so that salmonids can use it across all their life stages.

Figure 43 shows a typical section of the proposed channel geometry and Figure 44 compares it to cross-sections of the existing channel within the reference reach. The BFW and bank heights for the proposed channel are comparable to the reference reach BFW and bank heights. However, although the reference reach bank slopes on the overbanks are constrained by hillslopes, the proposed channel section will have somewhat broader floodplain benches.

The proposed channel width is 10 feet with a maximum depth of approximately 1.3 feet, and a 6-foot V-shaped low flow channel and 2:1 (H:V) bank slopes. To incorporate this typical cross-section within the structure, benches are added at 10:1 (H:V) slope. Figure 43 shows the proposed cross-section and corresponding water surface elevations at Station 4+25 for the proposed crossing.

The modeled 2-year water surface width in the proposed condition would be approximately 10 feet throughout the crossing, while BFW measurements within the proposed section outside the crossing would vary from 8 feet to 12 feet. Proposed conditions modeling shows that the stream overtops its banks in some areas downstream of the proposed grading limits during the 2-year event. However, the flow in the overbank areas is shallow (less than 0.2 feet) and could be either negligible or the result of computational rounding errors. Overall, the modeled 2-year flow would create a bankfull flow, as expected (see Figure 43).

Over time, the channel shape adjacent to proposed section as well as downstream section of the proposed structure is expected to change. The existing culvert has restricted flow upstream, and the drop barrier downstream of the existing culvert has reduced the energy of flow in the stream, thus affecting flows further downstream. So, with the proposed structure and the proposed channel section adjacent to the structure, the flow regime will change such that it will have higher velocities and bankfull flows downstream. As a result, the channel shapes in adjacent reaches of the proposed channel section will change. Finally, the proposed channel section should stabilize and create a natural transition between the structure and the adjacent natural channel. However, this change is dependent not only on the proposed channel shape, but also on the channel gradient, the change in upstream hydrology, and other site constraints.

Before the proposed section starts completely simulating the natural flow conditions of the adjacent reach, there might be cases in which natural flow was not simulated well for low-flow conditions with low depths, resulting in the proposed section acting as a low-flow barrier. In later stages of the project, a low-flow channel will be added that connects habitat features together, so that the project is not a low-flow barrier. The low-flow channel will be as directed by the engineer in the field.

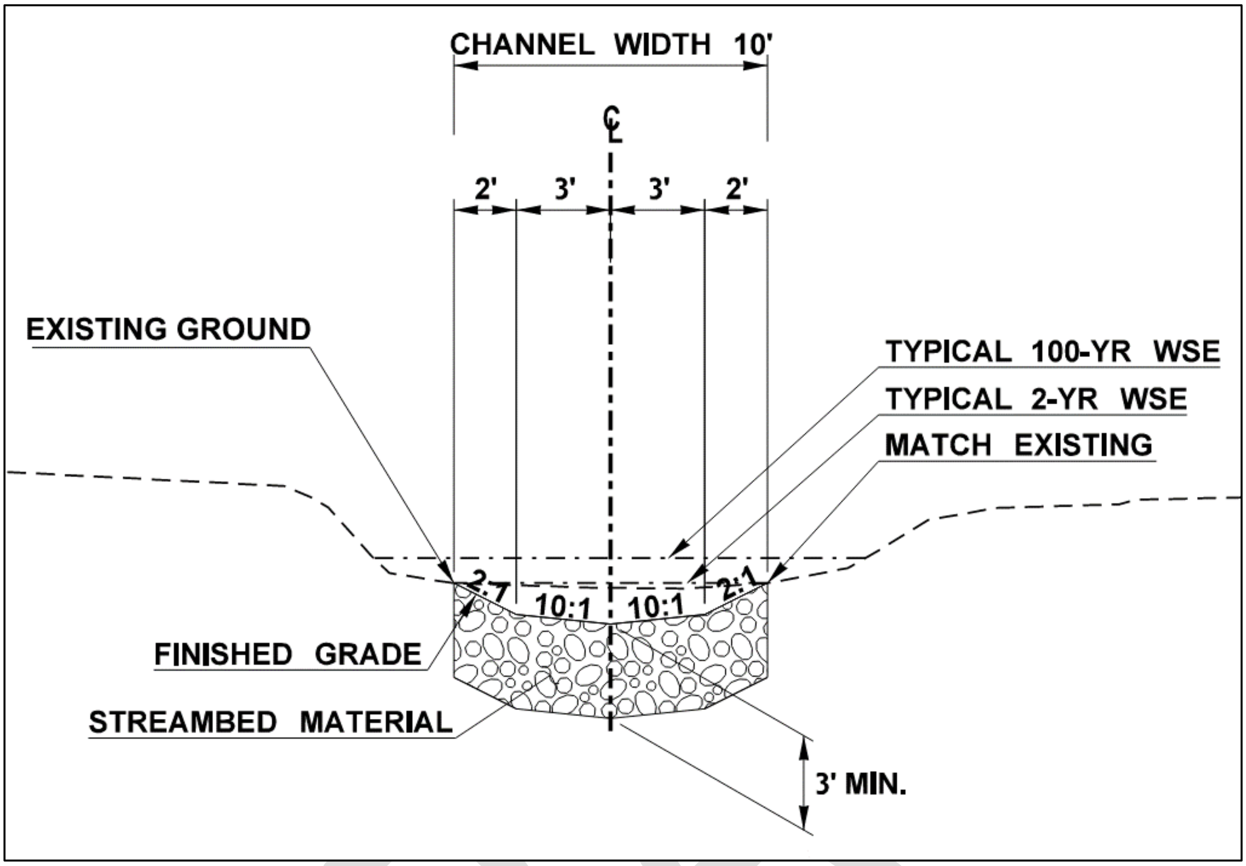


Figure 43: Design cross-section with 2-year and 100-year flow depths

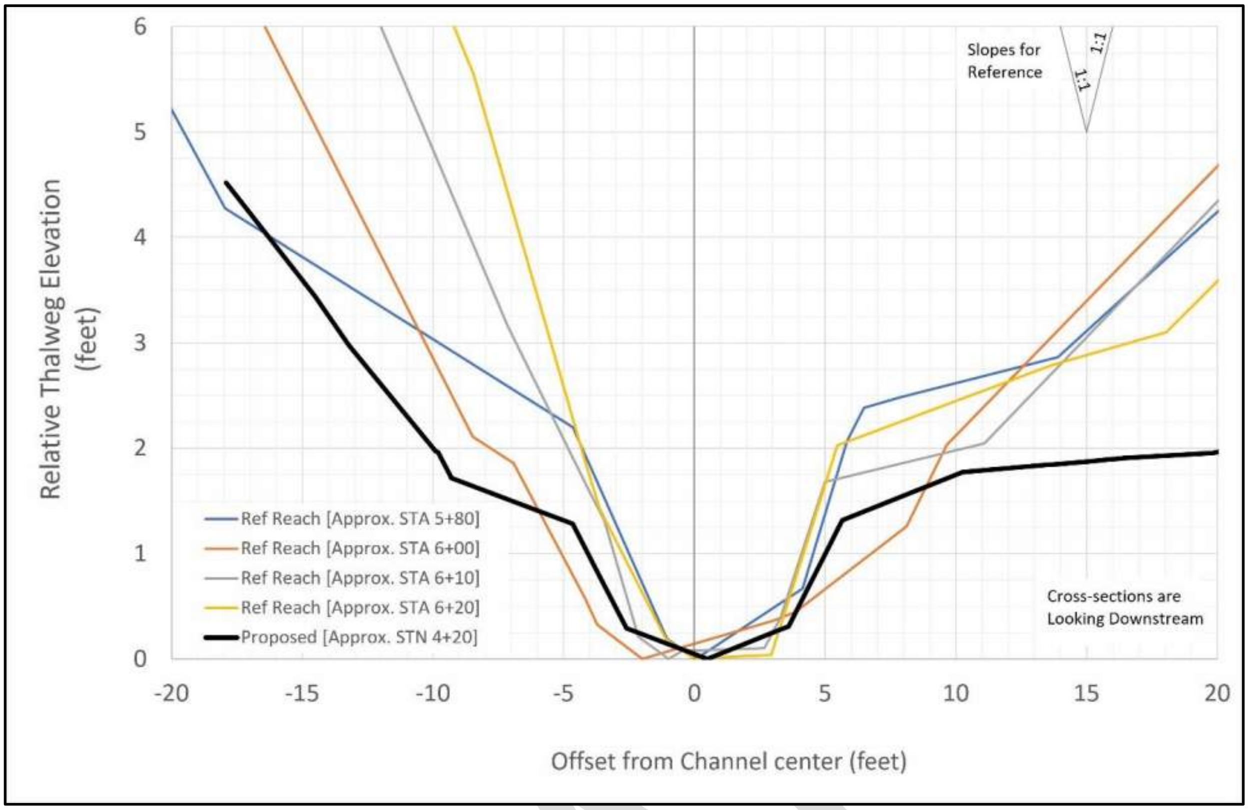


Figure 44: Proposed cross-section with existing survey cross-sections superimposed

4.1.2 Channel Alignment

The existing culvert crosses SR 3 at a perpendicular angle. Based on the likely historical alignment, it can be surmised that the channel was realigned to make the length of crossing as short as possible. Based on LiDAR and survey data, the channel alignment could have been a more direct, straighter path without the curves (see Figure 45). The radius of curvature of the stream at this location was roughly 35 feet. WCDG recommends that the radius of curvature of a design stream be at least five times the bankfull width. The bank full width of the stream is around 10 feet which would require the minimum radius of curvature to be at least 50 feet. However, multiple concurrence meetings involving representatives from WDFW, WSDOT, and Suquamish tribes included discussions of the channel alignment and this radius of curvature. Meeting participants agreed that the existing alignment would be preserved because this proposed alignment preserves channel length and has suitable bends for complex habitat even though the radius of curvature recommendation would not be fulfilled.

The total length of the channel grading is 312 feet, including about 67 feet of open channel upstream and 25 feet downstream of the structure, in addition to the 201-foot structure length. The channel follows hillslopes in the upstream end, and any changes that supports transitions to the existing stream in the channel alignment would be constrained mostly between the toes of the hillslopes.

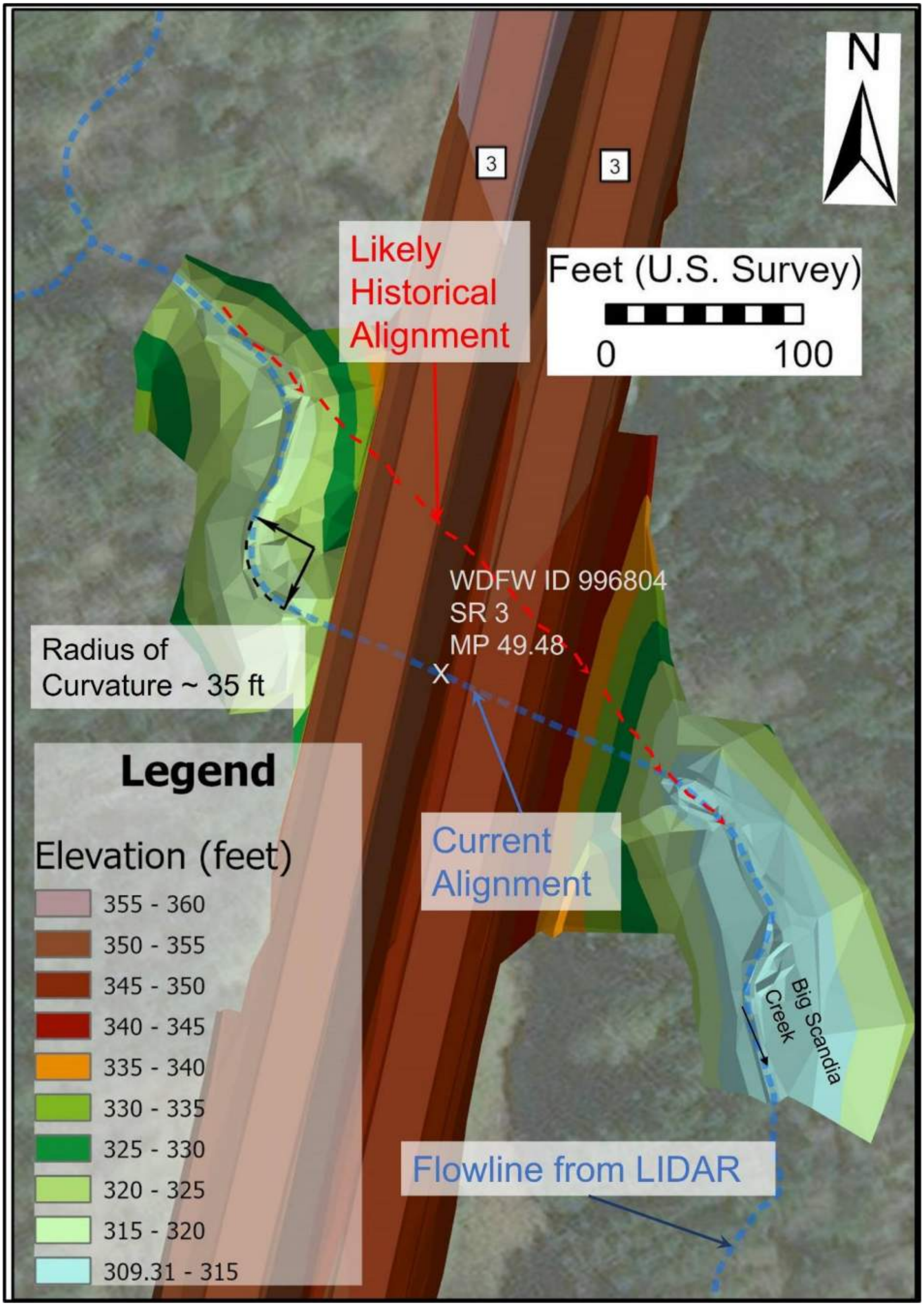


Figure 45: Current versus likely historical alignment of the channel

4.1.3 Channel Gradient

The proposed upstream channel tie-in point is at Station 4+70, which is roughly 67 feet upstream of the existing SR 3 culvert. The proposed downstream tie-in point is at Station 1+60, which is roughly 25 feet downstream of the existing SR 3 culvert. Selection of these tie-in locations was to avoid unusually high or low points in the existing thalweg and to mimic as closely as possible the adjacent stream grades. This grading eliminates the water surface drop at the exit of the existing culvert, which removes the crossing barrier. See the proposed profile in Appendix D.

The WCDG recommends that the proposed stream channel gradient be no more than 25 percent steeper than the upstream channel gradient, thus providing the limit of slope ratio of 1.25 (WCDG Equation 3.1). The slope of the proposed channel between tie-in points is 1.3 percent, while the existing slope upstream is also 1.3 percent, which results in a slope ratio of 1.0. The slope of the channel section at the reference reach is also about 1.3 percent. This consistency in slopes between the reference reach and graded channel section will provide a good transition between natural channel sections and the structure. Because the slopes are constant, long-term aggradation and degradation along the proposed channel section is expected to be minimal. See Section 7.2 for further discussion on aggradation.

4.2 Minimum Hydraulic Opening

The minimum hydraulic opening is defined horizontally by the hydraulic width, and the total height is determined by vertical clearance and scour elevation. This section describes the minimum hydraulic width and minimum vertical clearance; for discussion of the scour elevation, see Section 7. See Figure 46 for an illustration of the minimum hydraulic opening, hydraulic width, freeboard, and maintenance clearance terminology.

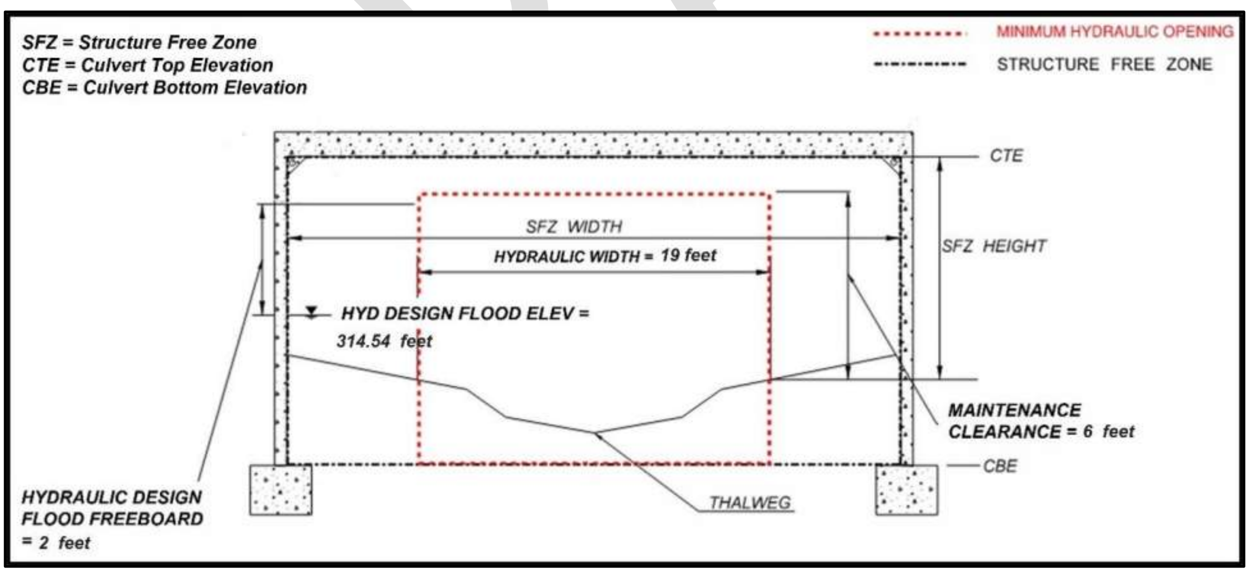


Figure 46: Minimum hydraulic opening – for illustration purposes only (NOT TO SCALE)

4.2.1 Design Methodology

The proposed fish passage design was developed using the WCDG (Barnard et al. 2013) and the WSDOT *Hydraulics Manual* (WSDOT 2022). Using the guidance in these two documents, the stream simulation design method was determined to be the most appropriate at this crossing because the BFW, FUR, and slope ratio fall within the applicable ranges. For stable streams with a BFW between 10 feet and 15 feet, where the culvert bed slope is no more than 125 percent of the upstream channel slope, the FUR is less than 3, and that have a light to medium proneness to debris, WCDG recommends the stream simulation approach as the best approach to design the crossing. For Big Scandia Creek, the agreed-upon average BFW is 10 feet, measured within the reference reach (see Section 2.7.2), and the average FUR is calculated to be 2.9, with even smaller FUR values in the reference reach (see Section 2.7.2.1). The proposed crossing length is 201 feet (see Section 4.1.2). The existing roadway elevation at the culvert inlet is approximately 352.8 feet and is approximately 37.7 feet above the proposed channel thalweg elevation. The existing roadway elevation at the culvert outlet is approximately 349.1 feet and is approximately 35.5 feet above the proposed channel thalweg elevation.

The slope ratio of the proposed channel is 1.0 (see Section 4.1.3), and the existing channel is also vertically and horizontally stable, which makes the stream simulation approach most suitable for the design of this crossing. However, there were a few constraints related to length of the crossing that, if not considered carefully during design, could inhibit natural processes such as lateral movement of channel and accelerated flow within the structure, causing scours at outlet and the possibility of creating another fish barrier in the long run. See Section 2.7.5 and Section 4.1.1 for more discussion on channel migration. To alleviate these concerns, improvements to the design include increasing the width of the structure to allow for additional complexity. This increase in complexity is achieved by adding point bars within the channel and increasing culvert roughness by adding meanders. The design also considers additional concerns, such as changing climate and urbanization of contributing watershed, which could increase the future high flows, by checking the adequacy of design in high flows using the hydraulic model. See Section 4.2.2 for the 100-year and projected 2080 100-year velocity comparison and its influence on design. This design is expected to mimic the reference reach and maintain channel stability without significant aggradation or degradation (see Section 7.2).

4.2.2 Hydraulic Width

The starting point for the minimum hydraulic width determination of all WSDOT crossings is Equation 3.2 of the WCDG, rounded up to the nearest whole foot. For this crossing, the equation yielded a minimum hydraulic width of 14 feet as the starting point.

For the stream simulation design method, the WCDG recommends sizing the span of a proposed structure based on the agreed-upon BFW, with the span being 1.2 x BFW + 2 feet (WCDG Equation 3.2). In addition, WSDOT (WSDOT, 2022a) recommends calculating the span using 1.3 x BFW and using whichever result is larger (WCDG equation or WSDOT equation). For Big Scandia Creek, given the agreed-upon BFW of 10 feet, using these equations result in 14 feet (WCDG) and 13 feet (WSDOT). Therefore, the minimum hydraulic opening should be 14 feet.

The WCDG also recommends that the length of the structure be checked against its span and, in some cases, increasing the minimum hydraulic opening due to excessive backwater, velocity differences between the crossing and the adjacent undisturbed reach, expected channel migration, or natural sinuosity of the channel, or if the proposed structure is considered a long crossing. Long crossings are defined as any crossings where the ratio of the crossing length to the minimum hydraulic opening exceeds 10. The length of the proposed SR 3 crossing is approximately 201 feet, which results in a length-to-width ratio of 14.3. The SR 3 crossing is thus considered a long crossing. Within long crossings, flows can accelerate within the structure. Small failures in long culvert bed structure during a flood event may cause a headcut within the culvert, which can expose the bottom and create a fish passage barrier (Barnard et. al., 2013). Additionally, natural sinuosity of the channel might be difficult to maintain within long culverts, because the structure might not be able to provide enough width to accommodate natural sinuosity. To account for meanders, the WCDG and WSDOT recommend increasing the minimum hydraulic opening width by a minimum of 30 percent for long crossings (Barnard et. al, 2013). However, this 30 percent increase in width needs to be evaluated in consideration of the site conditions to determine possible adjustments. For example, if a channel has shown high sinuosity on a flat slope in the past, this value of 30 percent might need to be increased.

For Big Scandia Creek, the overbanks are constrained by steep fill slopes, and the terrain data does not show high sinuosity. As such, a minimum hydraulic opening of 14 feet plus 30 percent (which amounts to 18.2 feet, or 19 feet when rounded up to the nearest foot) is expected to provide sufficient width for the channel to form some natural sinuosity across the designed structure. This factor of safety of greater than 30 percent should therefore compensate for chance events, and errors in measurements and design. Future design efforts should verify road design requirements and forward compatibility needs at the time of design, which could impact the length of the crossing.

Based on the factors described above, a minimum hydraulic width of 19 feet was determined to be necessary to allow for natural processes to occur under current flow conditions. The projected 2080 100-year flow event was evaluated. Table 7 compares the velocities of the 100-year event and the projected 2080 100-year event.

Table 7: Velocity comparison for 19-foot structure

Location	100-year velocity (feet/second [fps])	Projected 2080 100-year velocity (fps)
Upstream Station 6+00 (A)	3.9	4.2
Upstream Station 5+00 (B)	4.5	5.3
Upstream Station 4+25 (C)	1.6	1.6
Structure Station 3+00 (D)	3.3	4.5
Downstream Station 1+75 (E)	2.0	2.5
Downstream Station 1+00 (F)	3.1	4.0
Downstream Station 0+25 (G)	2.4	3.1

A minimum hydraulic opening width of 19 feet through the crossing will have more than adequate capacity to pass the 2080 100-year event, with only minor increases in velocity. The minimum hydraulic width will not create a backwater effect (see Figure 62).

No size increase was determined to be necessary to accommodate climate change. For detailed hydraulic results related to the minimum hydraulic width of the opening, see Section 5.4.

4.2.3 Vertical Clearance

The vertical clearance under a structure addresses two considerations: freeboard and maintenance clearance. Both are discussed below, and Table 8 summarizes vertical clearance results.

The minimum required freeboard at the project location, based on BFW, is 2 feet above the 100-year water surface elevation (WSE) (Barnard et al. 2013, WSDOT 2022).

WSDOT is incorporating climate resilience in freeboard, where practicable, and has evaluated freeboard at both the 100-year WSE and the projected 2080 100-year WSE. The WSE is projected to increase by 0.4 feet for the 2080 projected 100-year flow rate. The minimum required freeboard at this site will be applied above the projected 2080 100-year WSE to accommodate climate resilience.

The second vertical clearance consideration is maintenance clearance. WSDOT HQ Hydraulics determines a required maintenance clearance if a height is required to maintain habitat elements, such as boulders or LWM. If there are no habitat elements requiring maintenance clearance, the maintenance clearance is only a recommendation by WSDOT HQ Hydraulics, and the WSDOT region determines the maintenance clearance required.

The channel complexity features in Section 4.3.2 do not include elements of significant size and will not need to be maintained with machinery. If it is practicable to do so, a minimum maintenance clearance of 6 feet is recommended for maintenance and monitoring purposes but is not a hydraulic requirement. Maintenance clearance is measured from the highest streambed ground elevation within the horizontal limits of the minimum hydraulic width.

Table 8: Vertical clearance summary

Parameter	Downstream face of structure	Upstream face of structure
Station	2+10	4+12
Thalweg elevation (feet)	312.85	315.42
Highest streambed ground elevation within hydraulic width (feet)	314.56	317.13
100-year WSE (feet)	314.57	317.4
2080 100-year WSE (feet)	314.9	317.7
Required freeboard (feet)	2	2
Recommended maintenance clearance (feet)	6	6
Required minimum low chord, 100-year WSE + freeboard (feet)	316.57	319.4
Required minimum low chord, 2080 100-year WSE + freeboard (feet)	316.9	319.7
Recommended minimum low chord, highest streambed ground elevation within hydraulic width + maintenance clearance (feet)	320.56	323.13
Required minimum low chord (feet)	**316.57**	**319.4**
Recommended minimum low chord (feet)	**320.56**	**323.13**

4.2.3.1 Past Maintenance Records

WSDOT Area 2 Maintenance was contacted to determine whether there are ongoing maintenance problems at the existing structure because of LWM racking at the inlet or sedimentation. The maintenance representative indicated that there was no record of LWM blockage or removal, or sediment removal at this crossing.

4.2.3.2 Wood and Sediment Supply

The drainage basin for Big Scandia Creek upstream of the crossing is approximately 61 percent forest. There are no known plans for development or land cover changes in the basin. During site visits, very few pieces of LWM were observed in the stream. No WSDOT records of maintenance were present. However, there was some smaller woody material present in the stream as noted in Section 2.6.2. Given its 100-year flow of 69 cfs, the stream has limited ability to move LWM. We expect that this stream can transport up to 8-inch diameter log about 10-feet long with any real success. Any log with larger diameter will most probably get stuck at the banks. Upstream of the reference reach, we expect that wood transport would be less on the tributaries.

The creek appears to be in equilibrium from a sediment supply perspective; it has only limited signs of aggradation or degradation. With a consistently similar slope—1.3 percent upstream of the structure and 0.9 percent downstream of the structure—sediment supply is expected to be in equilibrium in the future. Presence of LWM would reduce the risk of channel incision by improving sediment storage and flow complexity. In addition, incorporating LWM would improve bank stability and protect from scour. The ability of a stream to move sediment is based on the bed shear stress in the channel, which is the critical shear stress for a particular size of sediment. See Appendix C for the critical shear stresses on sediments within the structure.

4.2.4 Hydraulic Length

A minimum hydraulic width of 19 feet is recommended up to a maximum hydraulic length of 201 feet. If the hydraulic length is increased beyond 225 feet, the hydraulic width and vertical clearance will need to be reevaluated.

4.2.5 Future Corridor Plans

There are currently no long-term plans to improve SR 3 through this corridor.

4.2.6 Structure Type

No structure type has been recommended by WSDOT HQ Hydraulics. The layout and structure type will be determined at later project phases.

4.3 Streambed Design

This section describes the streambed design developed for Big Scandia Creek at SR 3 MP 49.48.

4.3.1 Bed Material

The development of the proposed streambed mix followed methods recommended in the WCDG for sizing streambed material in culverts and in the WSDOT Hydraulics Manual

(WSDOT 2022). The proposed streambed mix design is intended to mimic PC-3 (see Section 2.7.3). The streambed material gradation was proportioned to mimic natural conditions to the extent practical using WSDOT standard streambed mixes. These bed material mixes are well-graded materials with larger, less mobile particle sizes as well as smaller particle sizes to produce a porosity that minimizes the opportunity for flow in the stream to go entirely subsurface during low-flow periods. The finer portion of the gradation will be composed of silts, sands, and small gravels to fill the interstitial spaces of the larger portions of the gradation. See Appendix C for streambed material design details.

Construction of the proposed streambed material should use 75 percent WSDOT Streambed Sediment (WSDOT Standard Specifications 9-03.11(1)) and 25 percent 6-inch cobbles (WSDOT Standard Specifications 9-03.11(2)). This standard material is somewhat larger than the existing streambed sediments (see Table 9 for a comparison), but streambed stability calculations still indicate that the streambed will be highly mobile. WSDOT Streambed Sediment has the smallest gradation sizes of the standard mixes without requiring a special provision. Scour calculations during later design stages will determine the minimum allowable streambed depth. This new proportion of streambed material will create higher quality spawning gravels as a result of less fine particulates within the streambed, increasing the likelihood of spawning in this stretch of the stream for all salmonid species present.

The Bathurst method for assessing streambed material, which WDFW recommends, is not recommended for use in streams having gradients less than 4 percent (Barnard et al. 2013). The proposed design slope for Big Scandia Creek is 1.7 percent. Therefore, the design process does not use the Bathurst method for assessing the streambed material. Instead, the modified Shields critical shear stress approach, as described in the U.S. Forest Service stream simulation guidelines (USDA 2008), was used to determine whether the proposed sediment sizes will be mobile or stable, as intended, during the full range of design flows. This method compares the critical shear stress for incipient motion for the D84 size fraction of the proposed streambed mixture to the average applied shear stress within the proposed grading limits for the 100-year peak flow. The incipient motions for flows other than 100-year peak flows were also checked. These channel stability calculations indicate that D84 sediments and D50 sediments will be mobile during flows less than the 2-year event. This does not reflect observed site conditions and may be due to the fact that the material in the existing streambed is consolidated and the modified Shields approach assumes unconsolidated material.

Meander bars are introduced in the channel not only to improve complexity but also to mitigate incipient motion of some of the streambed sediment at higher flows. Meander bars will have a minimum spacing of 15 feet through the restored channel area to increase channel stability. The spacing of 15 feet is assumed to be appropriate based on estimations of meander width downstream of the culvert. Meander bars will be incorporated such that a low-flow channel can be introduced that has enough complexity to facilitate fish passage through the structure. The meander bars should consist of 40 percent Streambed Sediment (WSDOT Standard Specifications 9-03.11(1)) and 60 percent 10-inch cobble materials (WSDOT Standard Specifications 9-03.11(2)). See Appendix C for results of this analysis of streambed material sizing.

The design of the bed materials that have a proposed diameter of D50 = 0.9 inches (see Table 9) will create a coarsened channel, which will reduce velocity and increase flow depths. These conditions can be helpful for larger fish that can also pass through longer reaches in search of upstream spawning habitat. For juvenile salmonids, the length of culvert is too long to pass through without added spots where they can rest. To address this need, the design includes a low-flow channel between meanders, which will create a meandering path that increases complexity by reducing the slope and velocity within the channel. This added complexity helps passage of fish at all stages of life.

Table 9: Comparison of observed and proposed streambed material

Sediment size	Observed diameter–PC3 (inches)	Proposed diameter (inches)	Meander bar diameter (inches)
$\mathbf{D_{16}}$	0.003	0.1	0.32
$\mathbf{D_{50}}$	0.3	0.9	1.9
$\mathbf{D_{84}}$	1.1	2.2	6.9
$\mathbf{D_{95}}$	1.8	4.8	9.5
$\mathbf{D_{100}}$	5.0	6.0	10.0

4.3.2 Channel Complexity

This section describes the channel complexity of the streambed design developed for Big Scandia Creek at SR 3 MP 49.48.

4.3.2.1 Design Concept

The channel design concept is a low-gradient plane-bed channel with some pools added via meander bars and LWM. Channel complexity features for the SR 3 crossing are designed to provide habitat and allow for natural stream processes. The channel complexity features for this crossing include LWM in open channel outside of the new structure (see Figure 47) for habitat. LWM comprises wood structures (trunks) greater than 6 feet in length and greater than 6 inches in diameter. LWM, used appropriately within a channel, can provide bank protection and channel resilience, and can offer benefits for aquatic habitat. Habitat provided by LWM can help provide aquatic life shelter from predators and higher velocity water, and can contribute to hyporheic flows, cooler waters, and gravel/sediment retention. The bed and bank morphology of the existing channel is stable; vegetation on the bank contributes to the stability of the channel. In open channel areas upstream and downstream of the proposed crossing, the proposed project will use LWM to add channel complexity and provide refuge for both adult and juvenile fish. No preformed pools are recommended.

The project will reconstruct 311 feet of channel, roughly 201 feet of which is expected to be within the new structure, if a culvert is constructed, leaving 110 feet of open channel area. A bridge design would increase the open channel length along the constructed reach. For this length of reconstructed channel, 12 key pieces and 36 total pieces of LWM are recommended (Fox and Bolton 2007). To achieve the recommended volume of wood, the LWM would need to be up to 4 feet in diameter at breast height (DBH). Pieces this size would be difficult to obtain, difficult to construct, and excessive for this 10-foot-wide channel. For these reasons, the recommended volume of wood is lower at this site.

Key pieces will consist of self-ballasting logs that are generally 1.5 feet to 2.0 feet DBH and 24 feet to 30 feet long. Additional pieces in the 1-foot DBH size range will be included along with the smaller wood in the 0.5-foot DBH size range. These smaller pieces would move only during extreme events and may not move far even during high flows, because they are likely to rack against larger wood pieces. Anchoring is anticipated until stability calculations are completed that indicate otherwise. Appendix F shows the recommended quantities of woody material for this channel. Figure 47 presents the approximate locations and orientation of this woody material. Figure 48 presents the approximate locations and orientation of the woody material if the assumed structure is a bridge. Bridges allow for additional LWM between the bridge decks. Note that both conceptual layouts place LWM within 50 feet of the structure which goes against WSDOT standards (WSDOT 2022). However, there is limited space for LWM placement and placing LWM within 50 feet of the structure is the only feasible way to meet the LWM volume requirements. This will require future coordination with WSDOT.

A low flow channel will be formed through the LWM which connects with the low flow channel formed between meander bars under the structure. Meander bars as well as LWMs are designed to be immobile during low and medium flow events. This helps to maintain the low flow channel even after a larger flow event. This low flow channel will assure that during low flows, there is no risk of fish stranding in the dry bed. These LWM anchors can not only provide stability but could also provide small pools which would improve habitat and provide refuge to juveniles during low flow summer months, and when migrating downstream. These LWM pools will be connected with the pools formed between meander bars and this series of connected pools will act cohesively to increase complexity and support fish passage as well as habitat. Juvenile coho, steelhead, and cutthroat trout will all directly benefit from this improved habitat, as they spend at least one year in the stream they spawn in until migrating out.

4.3.2.2 Stability Analysis

The stability analysis for LWM will be completed at final design.

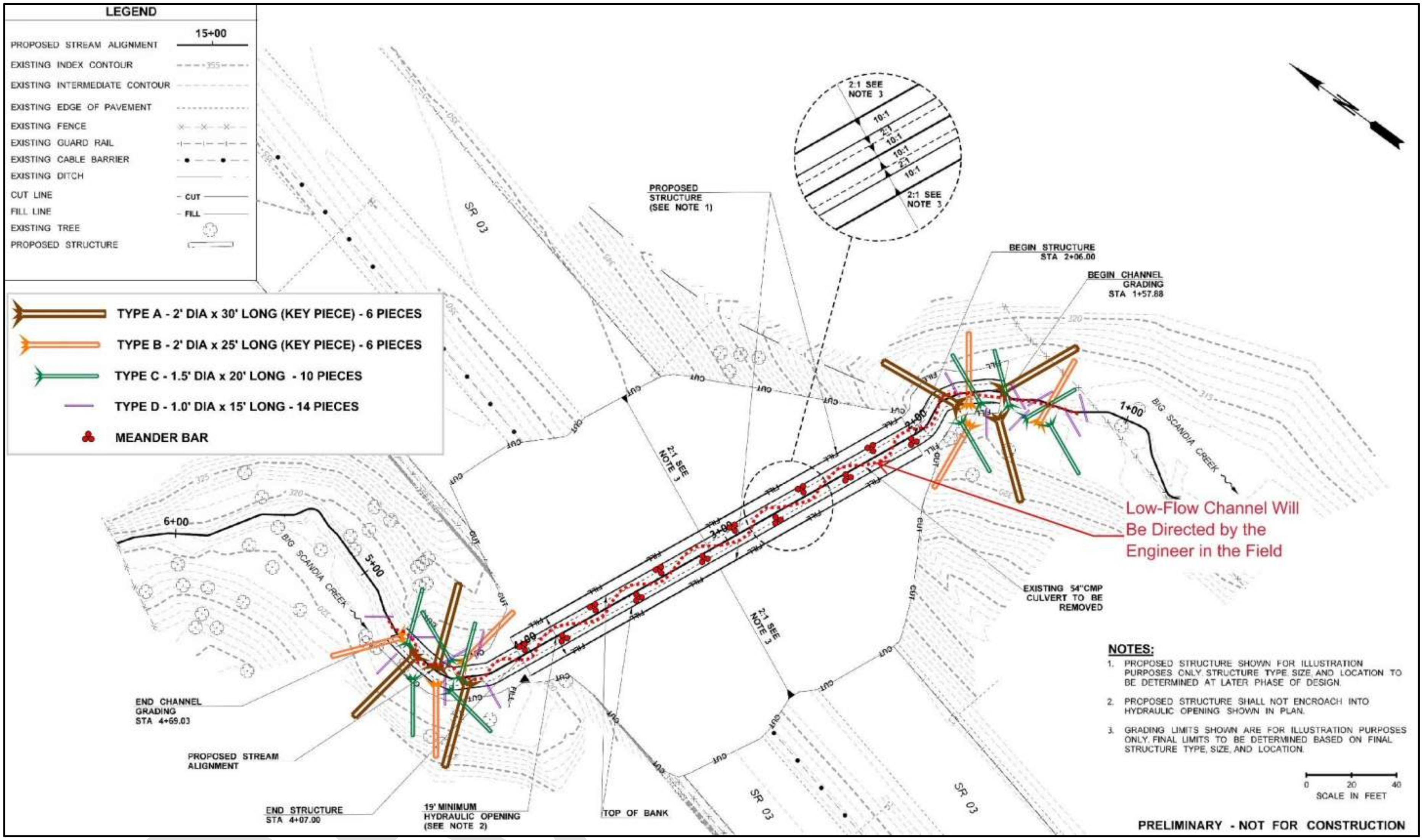


Figure 47: Conceptual layout of habitat complexity (Assumption structure type – Culvert)

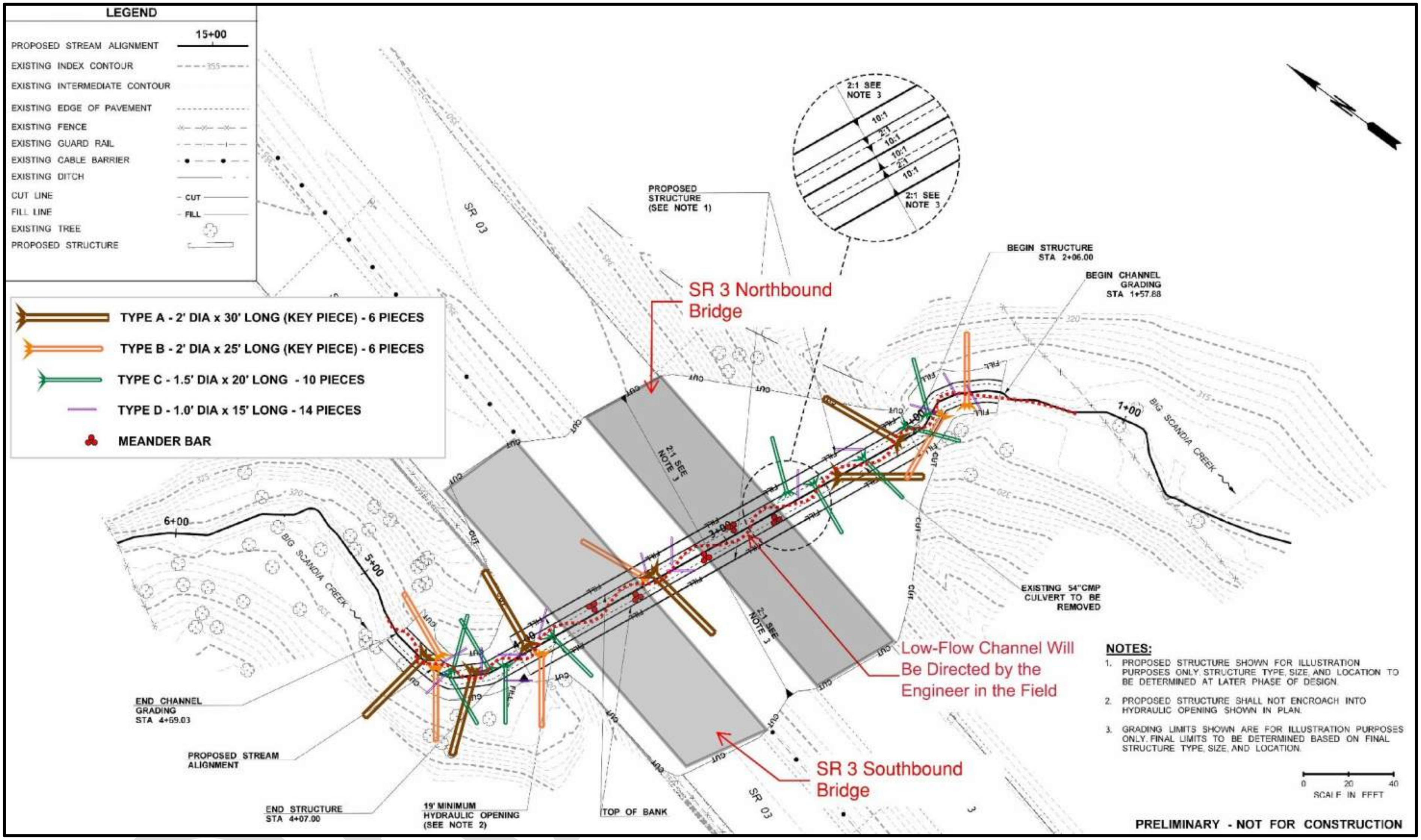


Figure 48: Conceptual layout of habitat complexity (Assumption structure type – Bridge)

5 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 3 Big Scandia Creek crossing was performed using the United States Bureau of Reclamation's SRH-2D Version 3.3.1 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model (USBR 2017). Pre- and post-processing for this model was completed using Surface-water Modeling System (SMS) Version 13.1.14 (Aquaveo 2021).

The analysis looked at two scenarios for determining stream characteristics for Big Scandia Creek with the SRH-2D models: (1) existing conditions with the 54-inch-diameter, 202.5-foot-long CMP culvert and (2) proposed conditions with the 19-foot minimum hydraulic opening, 201-foot-long structure installed.

5.1 Model Development

This section describes the development of the model used for the hydraulic analysis and design.

5.1.1 Topographic and Bathymetric Data

The channel geometry data in the model were obtained from the MicroStation and InRoads files supplied by the WSDOT Project Engineer's Office (PEO), which were developed from topographic surveys performed by WSDOT on September 9, 2021. The survey data were supplemented with light detection and ranging (LiDAR) data (WSDNR 2018). Proposed channel geometry was developed from the proposed grading surface created by DEA and Saez. All survey and LiDAR information is referenced against the NAVD 88 vertical datum.

Topographic surface development for proposed condition site geometry used Inroads software to regrade the surface through the crossing, extending roughly 67 feet upstream and 25 feet downstream of the existing SR 3 crossing. The proposed cross-section shown in Appendix D was used to model proposed conditions. To find an average consistent grade that minimized the increase in channel longitudinal gradient, the modeling used selected upstream and downstream match points to the existing profile. The topographic data was not updated to represent LWM or other habitat features under proposed conditions. Instead, surface roughness for these features were updated, as explained in Section 5.1.3.

5.1.2 Model Extent and Computational Mesh

The model extends from approximately 200 feet upstream of the existing SR 3 MP 49.48 inlet to approximately 200 feet downstream of the existing outlet, covering a total channel length of 630 feet (which also includes the selected reference reach). The model limits are selected to ensure that, at steady condition, the structure would not influence the flow at boundary conditions.

The model meshes have an element density that reflects the complexity of the site conditions. Both the existing conditions and the proposed conditions model consist of 14,043 elements (see Figure 49 and Figure 50) and covers about 77,000 square feet. The meshes for both the existing and the proposed conditions use quadrilateral elements in the channel and triangular elements over the remaining surface area. The meshes have an approximate vertex spacing of 1.5 feet along the channel banks and an approximate vertex spacing of 8 feet near the outer domain limits. Vertex spacing is 2 feet at the upstream boundary and 2 feet at the downstream boundary. The vertex spacing varies through the channel: there are higher densities at the crossing and along channel bends for an increased level of detail at these locations. The SR 3 crossing in the proposed model has an average vertex spacing of 1.5 feet along the structure walls and 0.9 feet at the inlet and outlet.

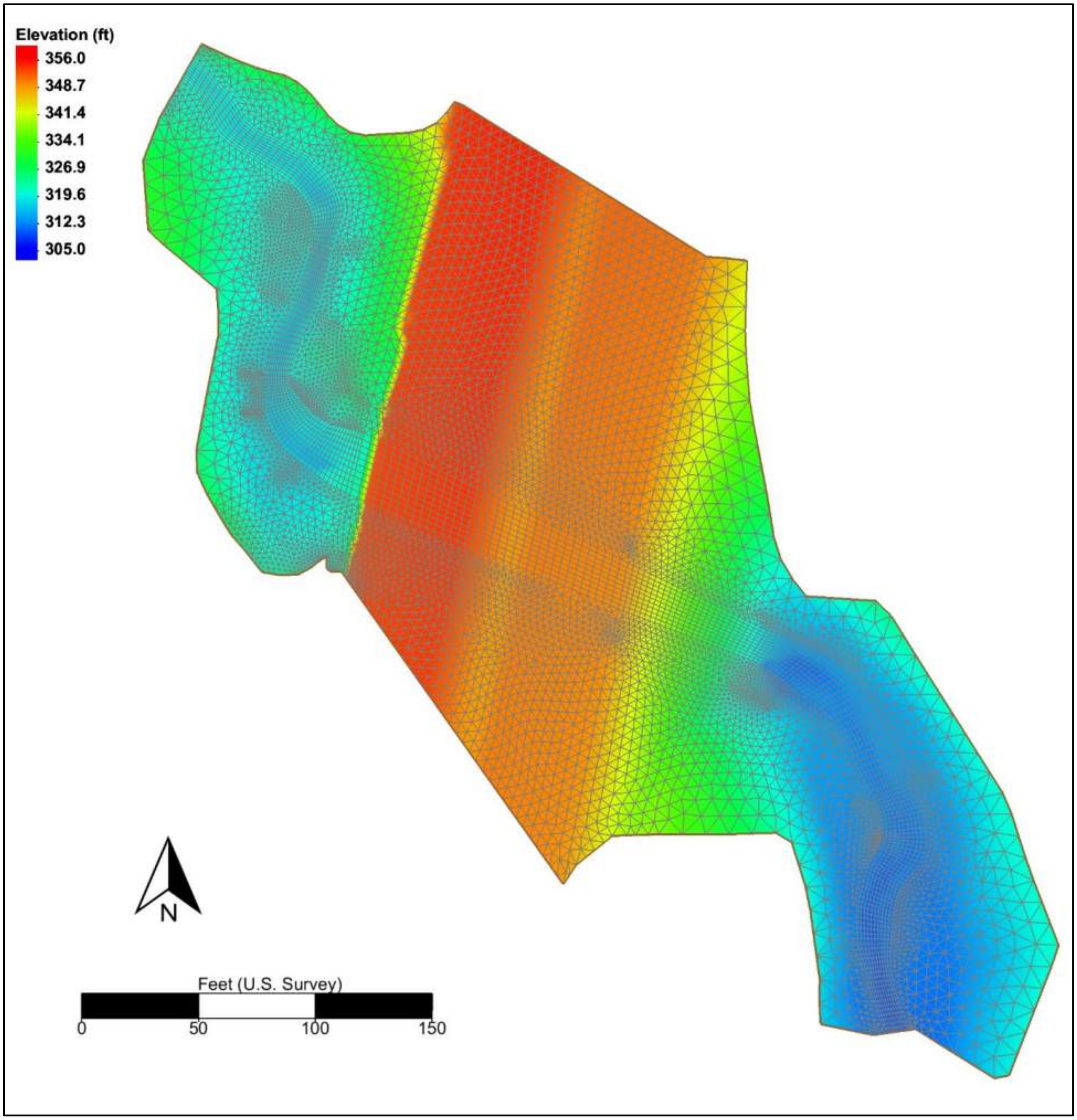


Figure 49: Existing conditions computational mesh with underlying terrain

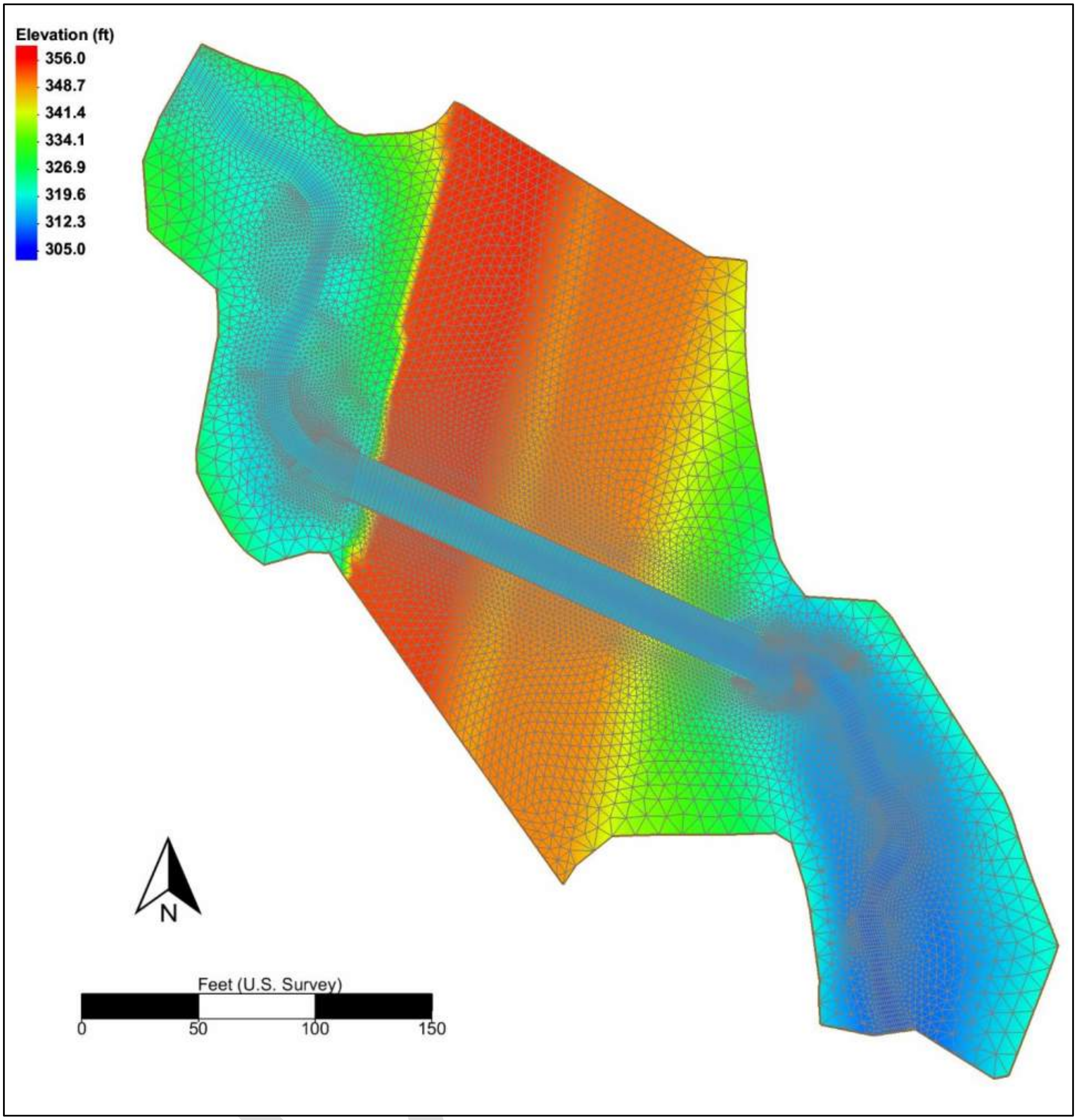


Figure 50: Proposed conditions computational mesh with underlying terrain

5.1.3 Materials/Roughness

Table 10 lists the roughness coefficients used in the hydraulic modeling taken from Open Channel Hydraulics (Chow 1959). Under existing conditions, the channel is well-defined, and flows within the channel are not hindered. There are a few debris drops in the channel, but one of the site visits observed that these small debris drops are washed during smaller storm events. Therefore, they have not been included in the representation of channel roughness. The floodplain outside the channel has a slightly higher roughness due to the vegetation. Existing conditions use the following roughness values listed in Table 10 and shown on Figure 51.

Table 10: Manning's n hydraulic roughness coefficient values used in the SRH-2D model for existing conditions (Chow, 1959)

Material	Manning's n coefficient
Road (asphalt)	0.02
Streambed (channel)	0.033
Floodplain (Light brush and trees)	0.05

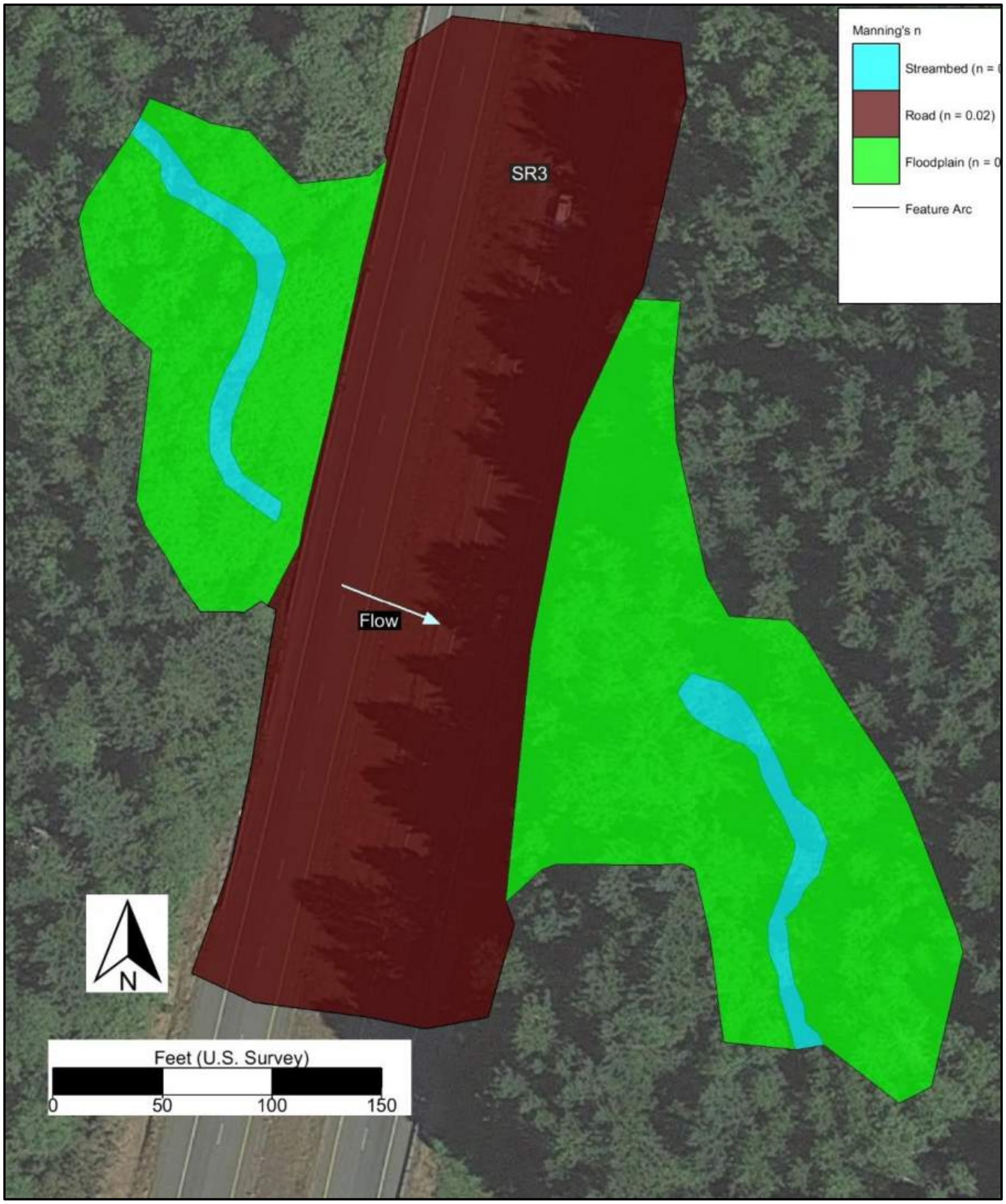


Figure 51: Spatial distribution of existing conditions roughness values in SRH-2D model

For proposed conditions, the roughness of the proposed channel section is increased, because the section includes proposed LWM and meander bars. Table 11 and Figure 52 present the roughness of the materials in proposed condition model.

Table 11: Manning's n hydraulic roughness coefficient values used in the SRH-2D model for proposed conditions (Chow, 1959)

Material	Manning's n coefficient
Road (asphalt)	0.02
Streambed (channel)	0.033
Floodplain (Light brush and trees)	0.05
LWM streambed	0.08
Culvert with meanders	0.04

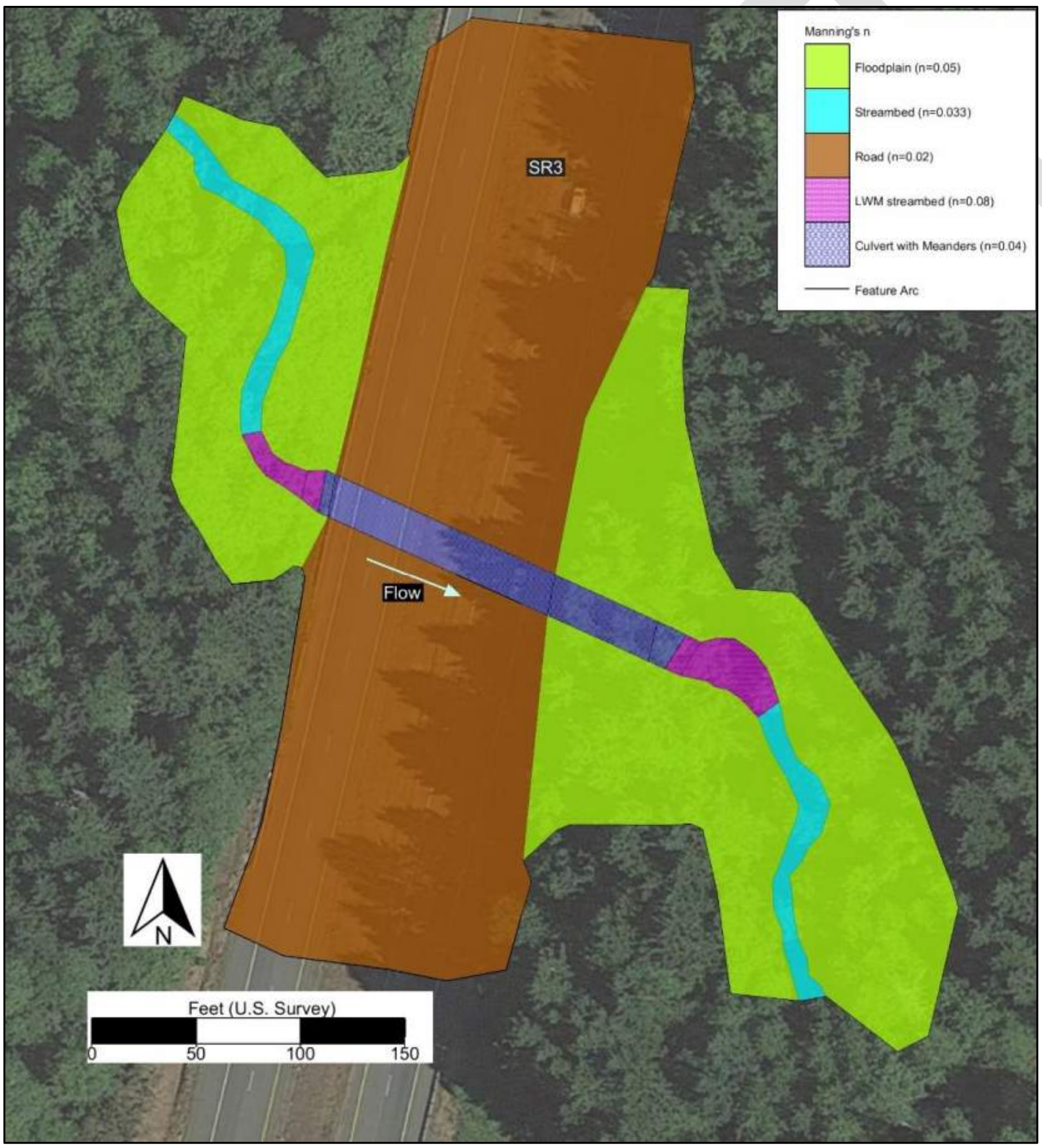


Figure 52: Spatial distribution of proposed conditions roughness values in SRH-2D model

5.1.4 Boundary Conditions

The SRH-2D model uses boundary conditions at locations where flow enters or leaves the model, including where the model simulates the culvert hydraulics by running the Federal Highway Administration's HY-8 culvert analysis software, embedded in Aquaveo SMS platform. The existing conditions model contains four boundary conditions: an inflow rate at the upstream limits, an inlet boundary and outlet boundary at the ends of existing culvert location for HY-8 (see Figure 53), and a steady state WSE at the downstream limits of the model. The proposed conditions model includes two boundary conditions: an inflow rate at the upstream limit and a WSE at the downstream limit. Figure 54 shows the rating curve for the downstream boundary condition. Figure 55 and Figure 56 show the locations of these boundaries in the existing and proposed conditions models, respectively.

The model specifies the upstream inflow boundary as a constant flow rate corresponding to the peak flow for the recurrence interval being modeled (i.e., peak flows equal to the 2-, 100-, 500-, and 2080 100-year flows). Table 6 in Section 3 provides these flow rates. The downstream outflow boundary was set for the normal water depth elevation using a composite Manning's n coefficient of 0.035, a slope of 0.017 feet per foot for existing conditions as well as for proposed conditions, and corresponding flows for each event. The inflow and outflow boundary conditions were set far enough away from the SR 3 MP 49.48 crossing so that they do not influence the hydraulic results at the project site. The model was run until steady state was reached for all simulations.

The existing conditions model used an additional pair of boundary condition arcs to simulate the existing 4.5-foot-diameter culvert. The SRH-2D model simulated the culvert hydraulics by running the Federal Highway Administration's HY-8 culvert analysis software as an embedded program within SMS. The paired-culvert boundary condition was used as an interface between SRH-2D and HY-8 within SMS. Culvert geometry, culvert type, and other relevant site data required for the HY-8 computations were compiled from the WSDOT survey and DEA site visits. Figure 53 shows the HY-8 input data for the existing culvert conditions.

For the proposed conditions model, because the structure is embedded in the model surface, boundary conditions for a culvert were not necessary. The proposed conditions model used only upstream inflow and downstream outflow boundary conditions without HY-8.

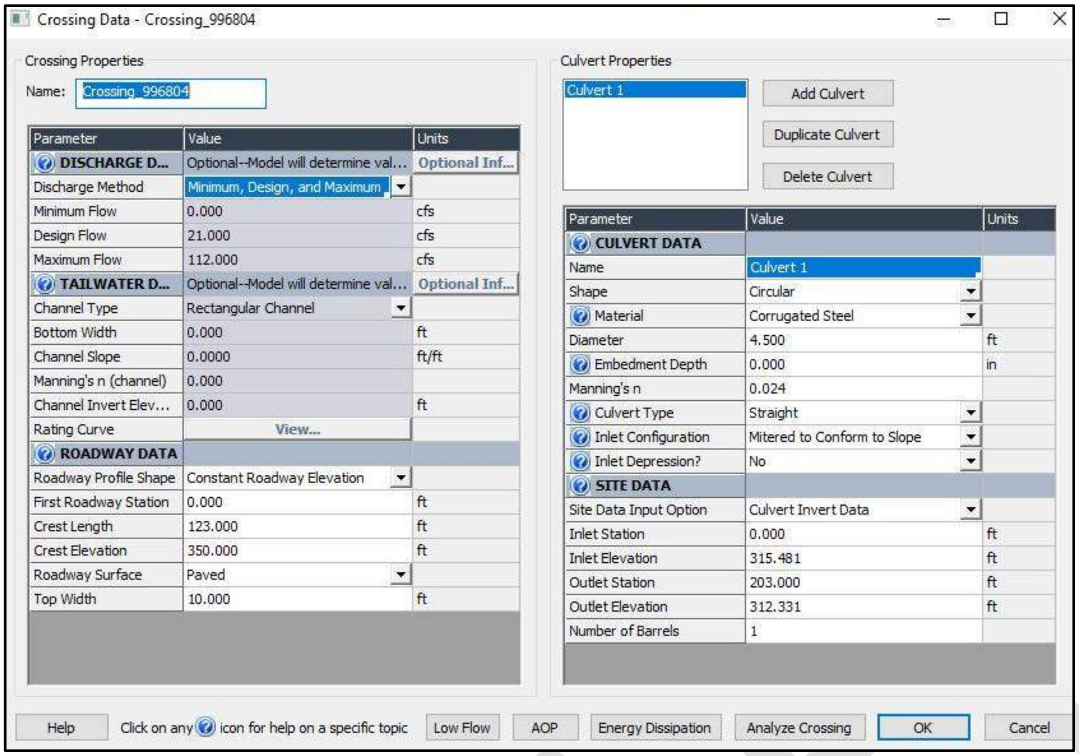


Figure 53: HY-8 culvert parameters

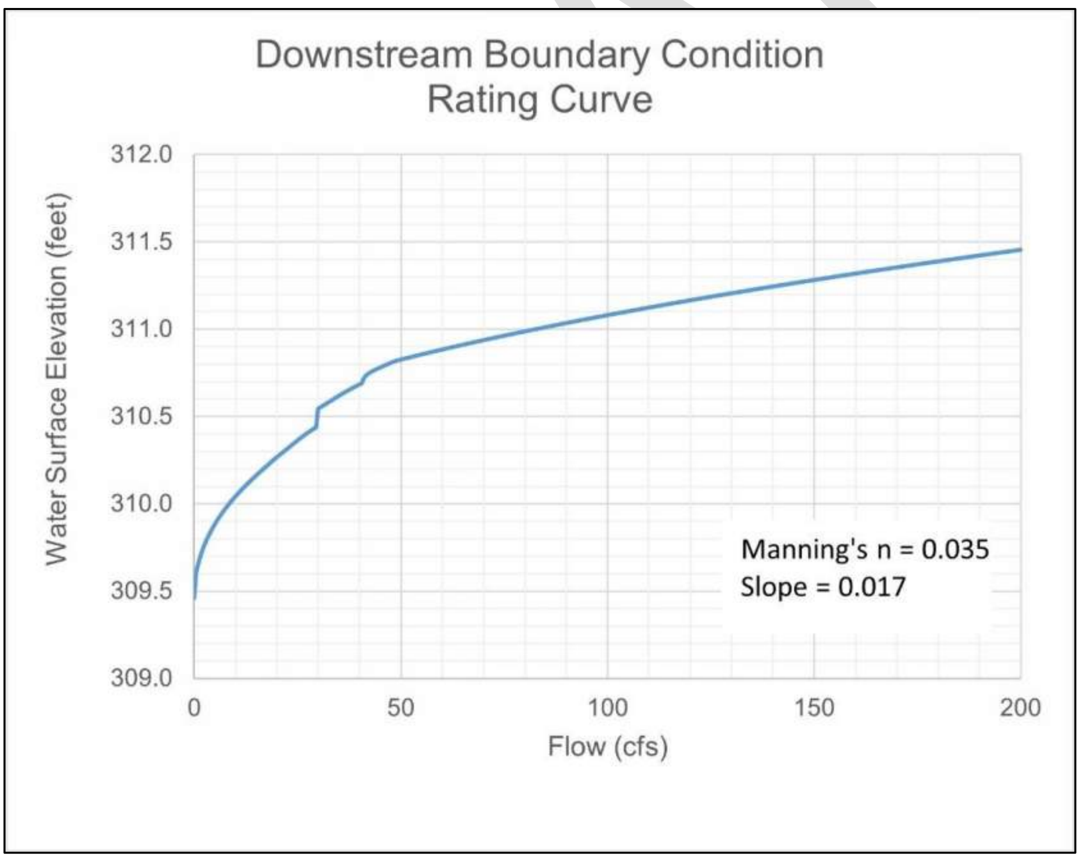


Figure 54: Downstream outflow boundary condition normal depth rating curve

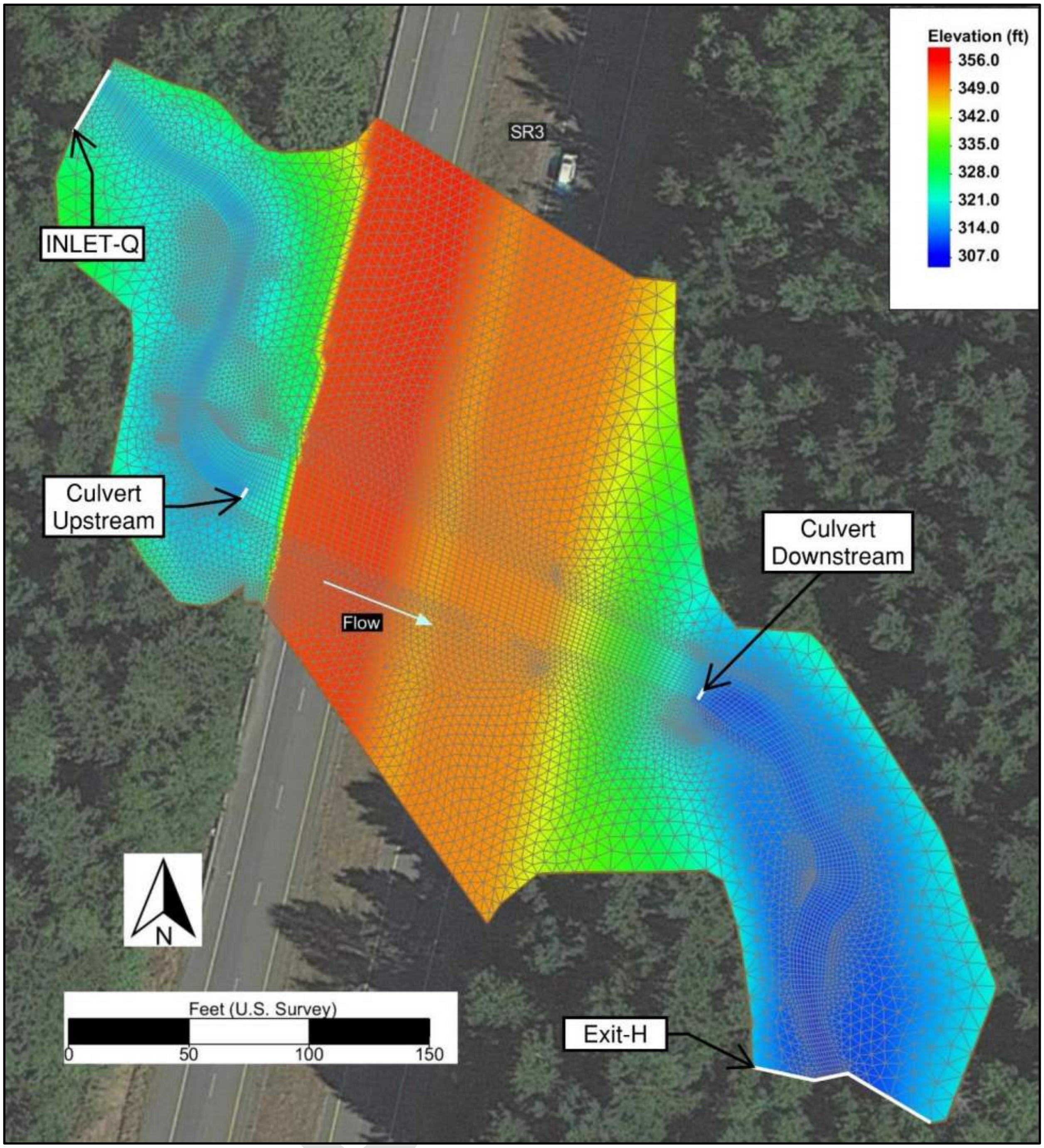


Figure 55: Existing conditions model – boundary conditions

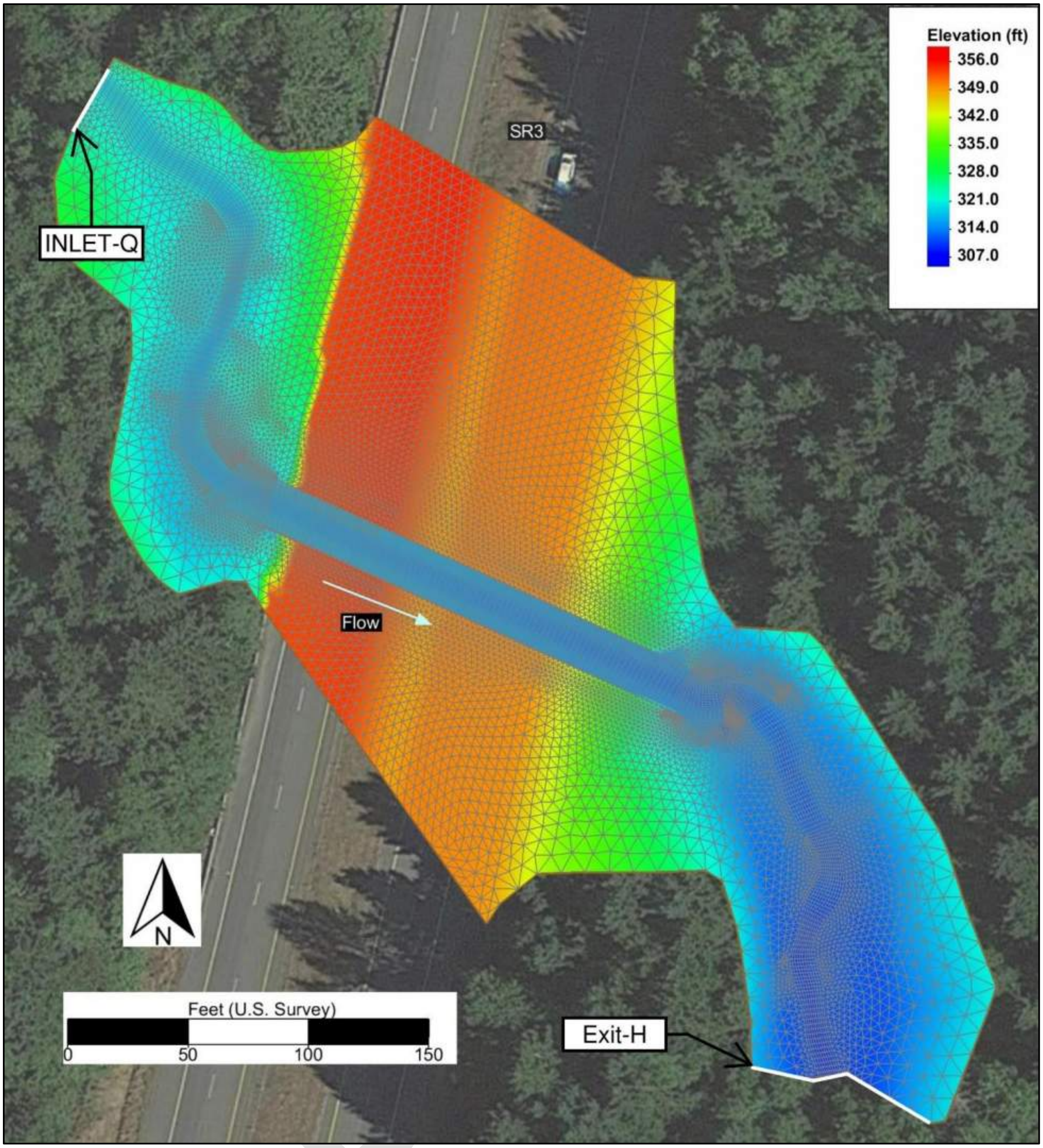


Figure 56: Proposed conditions model – boundary conditions

5.1.5 Model Run Controls

The existing conditions and proposed conditions models ran for long enough so that no observable changes in the WSE at the boundaries were observed. The existing conditions model ran with default parameters for turbulence for 5 hours of simulation time with 0.5-second time steps, but it typically achieved steady state conditions in less than 1 hour of simulation time. The proposed conditions model also ran for 5 hours of simulation time with 0.5-second time steps and achieved state-state conditions within 1 hour of simulation time. Both existing and proposed simulations began with a dry initial condition and event-specific flow values. Refer to Appendix I for model stability plots.

The existing and proposed models underwent a QC check on April 18, 2022.

5.1.6 Model Assumptions and Limitations

The models assume that all the basin's flow enters the channel at the upstream boundary condition in a uniform condition, even though the runoff between SR 3 and the upstream boundary condition would enter the channel throughout this reach. Although the simulation is unsteady, the assumption is that it reaches steady conditions after a certain period of time. No high-water marks or other indicators were available for calibration.

5.2 Existing Conditions

Table 12 presents the existing conditions model results. **Error! Reference source not found.** Figure 57 shows the locations of the cross-sections in the model where this data was measured. The existing culvert at the SR 3 crossings conveys all flows between the 2-year and 500-year intervals without overtopping the road. The maximum modeled flow through the existing structure is 90 cfs. There was minimal backwater for 2-year flows, but the 100- and 500-year flows caused some backwater at the existing culvert location (see Figure 58). Figure 59 shows a typical cross-section of the channel in existing conditions under these flows. The main channel extents, and the right overbank and left overbank locations were approximated by identifying the water surface top widths for the 2-year event within the model.

Maximum flow depth within the modeled area was about 2.5 feet during the 2-year event, where the existing channel was deeper in the upstream sections and the section with the water surface drop at the outlet of culvert. Velocities during the 2-year event along the stream ranged from 3.3 feet per second (fps) to 0.84 fps. Due to the backwater condition upstream, lower velocities are observed at the upstream inlet. Figure 60 shows the velocity along the channel for the 100-year event. There are high velocities at the water surface drop location downstream of the culvert. The channel constriction at some locations also results in higher velocities (see Table 13). Appendix H presents the spatial model results for these variables.

Table 12: Average main channel hydraulic results for existing conditions

Hydraulic parameter	Cross-section	2-year (21 cfs)	100-year (69 cfs)	500-year (90 cfs)
Average WSE (feet)	US STA 6+00 (A)	319.0	319.7	320.1
	US STA 5+00 (B)	317.8	319.4	320.2
	US STA 4+25 (C)	317.4	319.4	320.1
	STRUCTURE STA 3+00 (D)	NA	NA	NA
	DS STA 1+75 (E)	313.2	313.6	313.4
	DS STA 1+00 (F)	311.9	312.2	312.3
	DS STA 0+25 (G)	310.9	311.2	311.4
Maximum depth (feet)	US STA 6+00 (A)	0.8	1.5	2.0
	US STA 5+00 (B)	1.5	3.1	3.9
	US STA 4+25 (C)	1.7	3.6	4.4
	STRUCTURE STA 3+00 (D)	NA	NA	NA
	DS STA 1+75 (E)	1.9	2.2	1.9
	DS STA 1+00 (F)	0.7	1.0	1.1
	DS STA 0+25 (G)	1.0	1.7	1.9
Average velocity (fps)	US STA 6+00 (A)	3.2	4.3	4.3
	US STA 5+00 (B)	2.2	2.8	2.2
	US STA 4+25 (C)	0.8	1.1	1.1
	STRUCTURE STA 3+00 (D)	NA	NA	NA
	DS STA 1+75 (E)	1.5	4.1	5.4
	DS STA 1+00 (F)	3.1	5.1	5.6
	DS STA 0+25 (G)	1.6	2.8	3.2
Average shear (pounds per square foot)	US STA 6+00 (A)	0.6	0.9	0.7
	US STA 5+00 (B)	0.2	0.2	0.1
	US STA 4+25 (C)	0.1	0.1	0.0
	STRUCTURE STA 3+00 (D)	NA	NA	NA
	DS STA 1+75 (E)	0.1	0.6	1.2
	DS STA 1+00 (F)	0.5	1.0	1.1
	DS STA 0+25 (G)	0.3	0.5	0.6

NOTE: Main channel extents were approximated by using 2-year event water surface top widths.
NA = Not applicable.

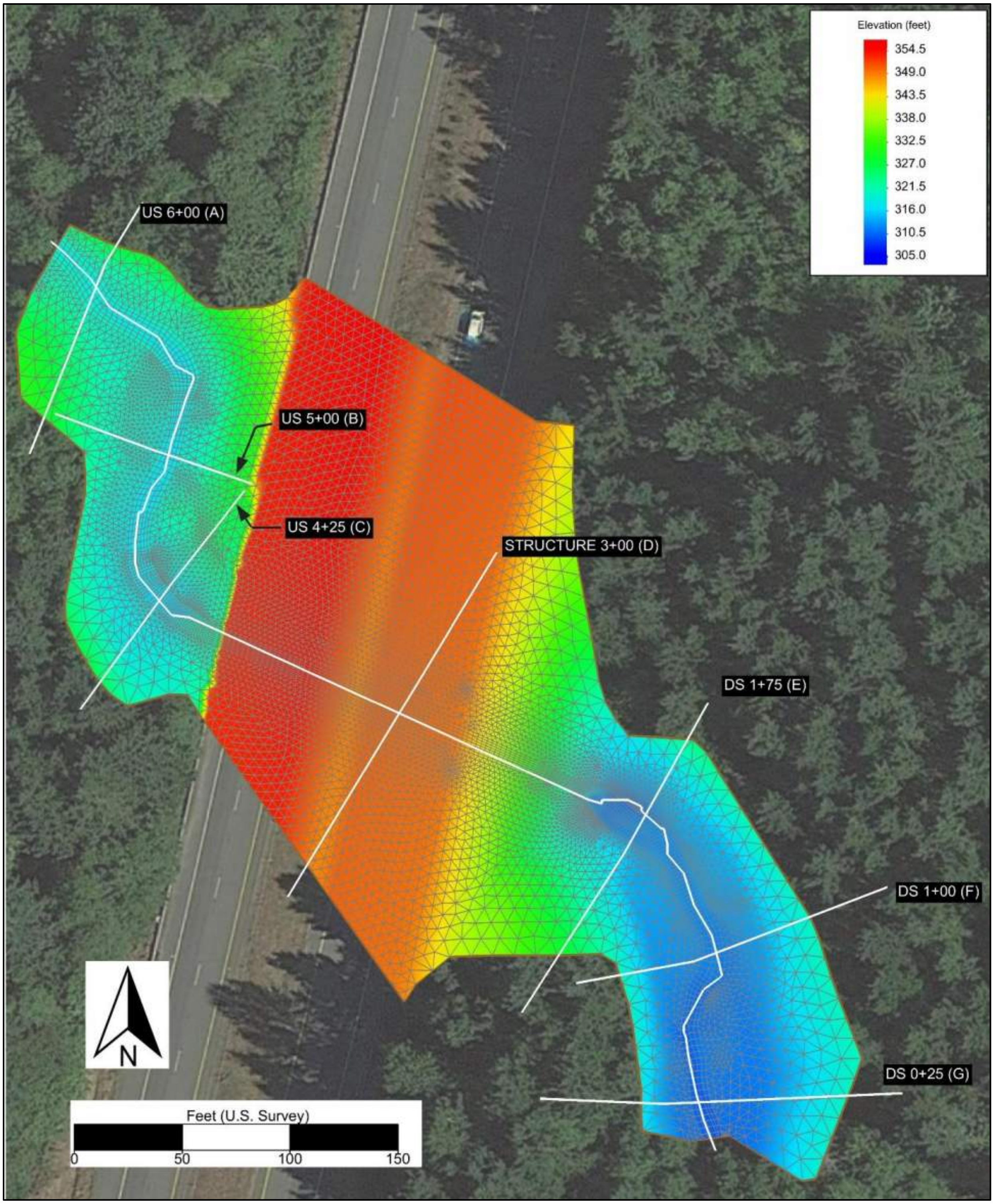


Figure 57: Locations of cross-sections used for results reporting

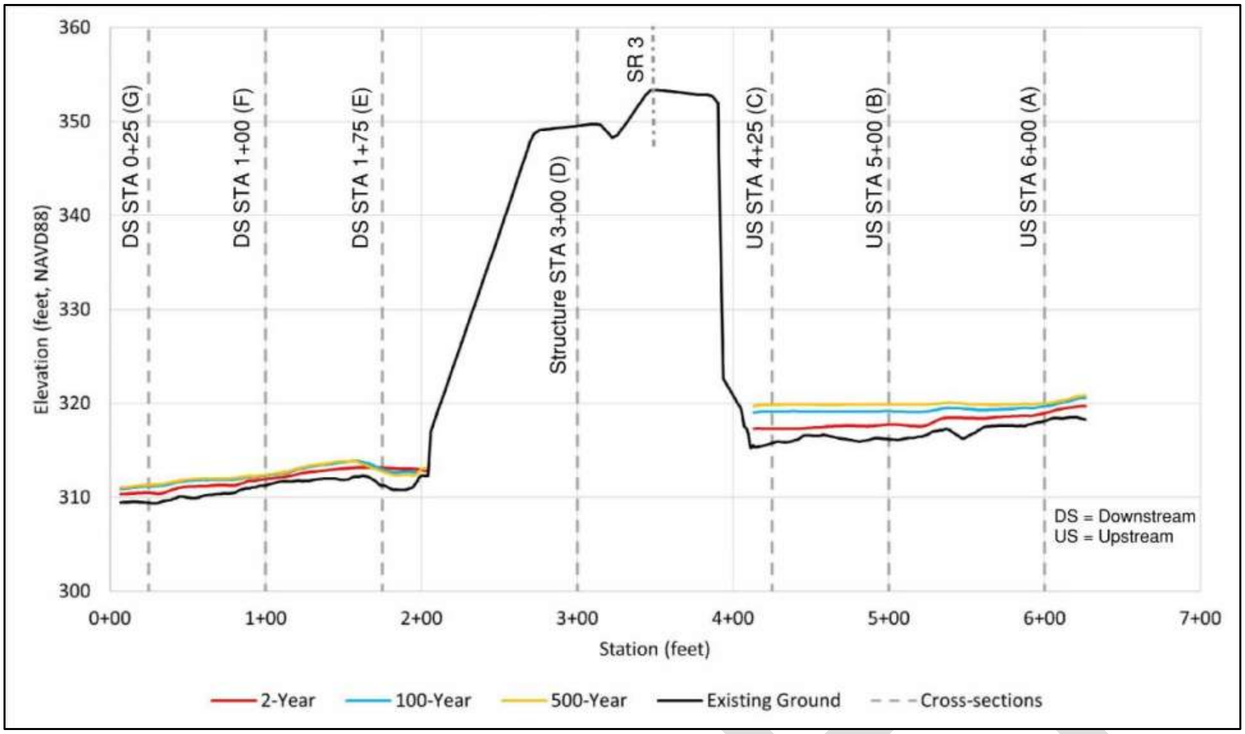


Figure 58: Existing conditions water surface profiles

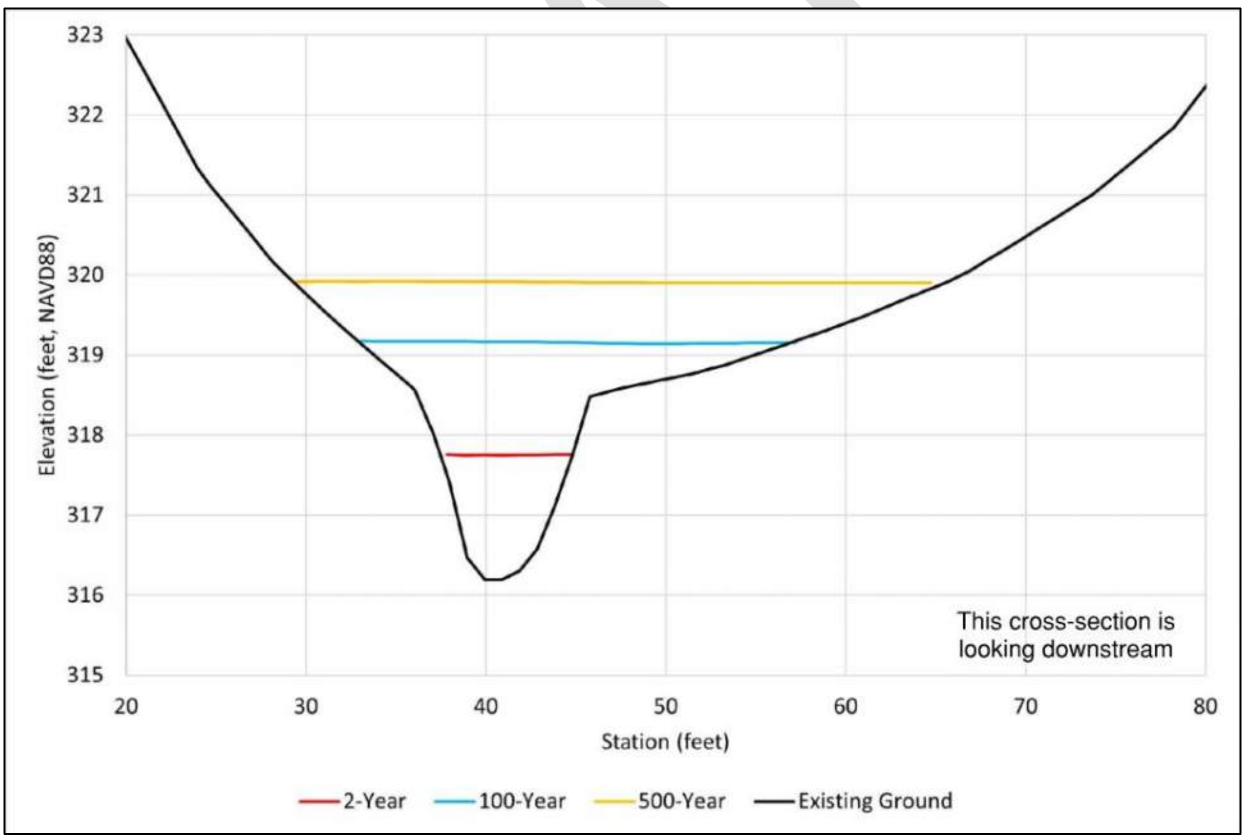


Figure 59: Typical upstream existing channel cross-section (Station 5+00)

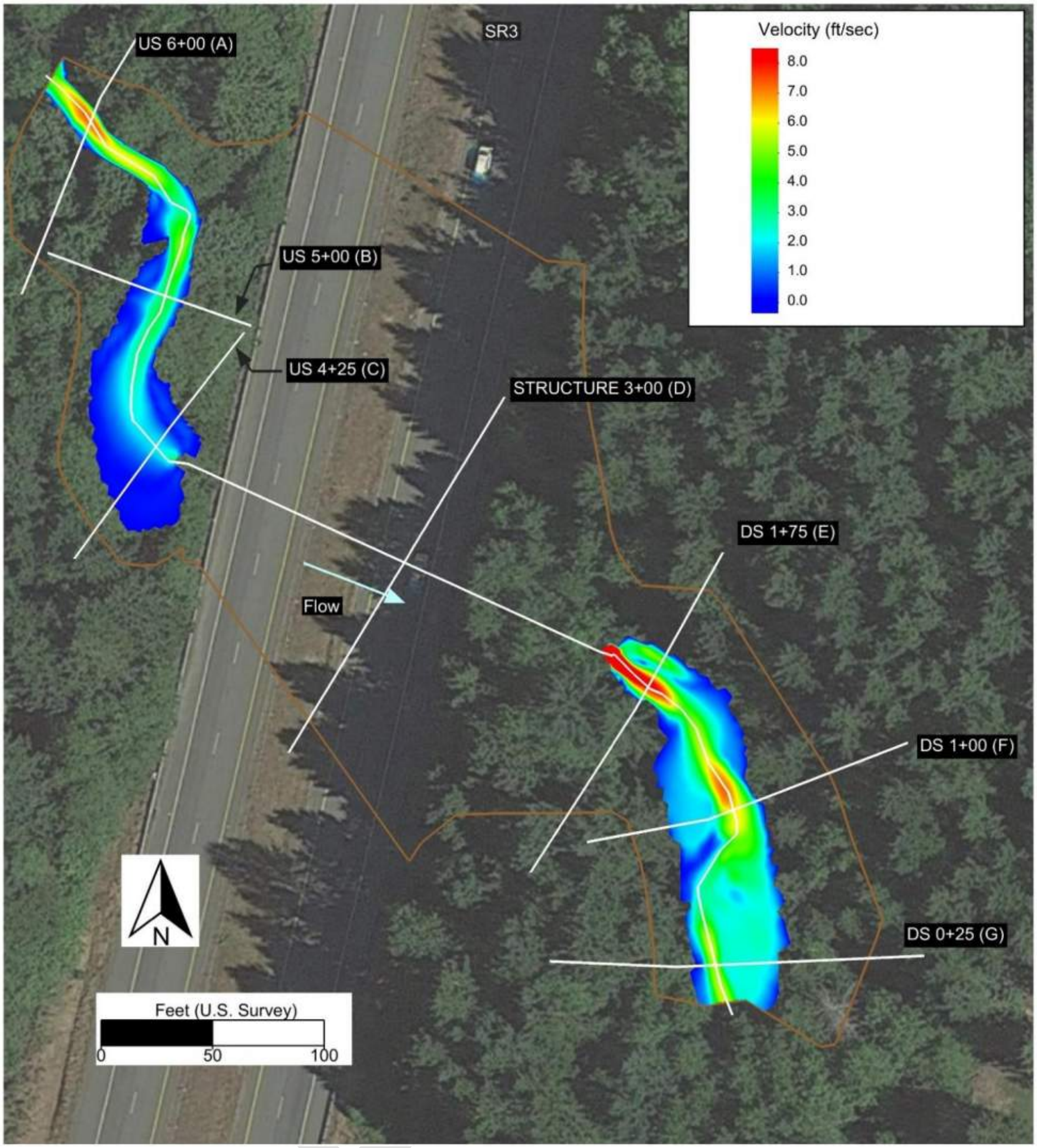


Figure 60: Existing conditions 100-year velocity map with cross-section locations

Table 13: Existing conditions average channel and floodplains velocities

Cross-section location	Q100 average velocities (fps)		
	LOB*	Main channel	ROB*
US STA 6+00 (A)	0.0	4.3	0.3
US STA 5+00 (B)	1.9	2.8	0.9
US STA 4+25 (C)	0.4	1.1	0.1
STRUCTURE STA 3+00 (D)	NA	NA	NA
DS STA 1+75 (E)	0.0	4.1	1.9
DS STA 1+00 (F)	2.5	5.1	1.7
DS STA 0+25 (G)	0.0	2.8	1.2

*Left overbank (LOB) and right overbank (ROB) locations were approximated using 2-year water surface widths.
NA = Not applicable.

5.3 Natural Conditions

Because the system is confined, a natural conditions model was not required.

5.4 Proposed Conditions: 19-foot Minimum Hydraulic Width

The hydraulic width is defined as the width perpendicular to the creek beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic modeling assumes vertical walls at the edge of the minimum hydraulic width unless otherwise specified. See Section 4.2.2 for a description of how the minimum hydraulic width of 19 feet was determined.

The proposed conditions model replaces the existing SR 3 culvert with a 19-foot hydraulic opening width entered as an open-channel cut across SR 3. This approach does not use culvert representation (HY-8) at the crossing, because the intent is to simulate stream functions within the structure. The proposed conditions model also includes 67 feet of open channel grading upstream of the structure and 25 feet of open channel grading downstream of the structure. Table 14 presents the calculated WSE, velocity, depths, and shear stress from the proposed conditions SRH-2D model for 2-year, 100-year, 500-year, and 2080 100-year peak flows. Appendix H includes the spatial distribution of these variables. Figure 61 shows the locations of these cross-sections.

Figure 62 shows the profiles of existing and proposed surfaces along with water surface elevations of each flow event. As seen in the figure, the water surface drop barrier has been removed at the outlet of culvert in the proposed conditions. Backwater conditions observed in the existing model for higher flows have been eliminated. The 100-year flow depth within the channel through the structure is 1.7 feet, which is similar to the upstream and downstream depths, which are 2.1 and 1.9 feet, respectively (see Figure 63). It is expected that over time, the channel will naturally adjust, and depth and velocities will transition even better to the upstream and downstream values.

Maximum flow depths within the modeled area range from 0.7 foot to 1.5 feet during the 2-year event. Velocities during the 2-year flow event along the channel profile range from 1.5 fps to

6.3 fps, with the regraded section velocities ranging from 3.5 fps to 4.4 fps. Figure 64 shows the 100-year velocities. The 100-year velocities are higher at certain upstream sections than those in the existing conditions model, likely because of removing backwater conditions at the inlet of the culvert. The average 100-year velocities along the stream range from 2.8 fps to a maximum of 5.1 fps (see Table 15). At some constricted sections of the channel, the velocities increase to a maximum value of 7 fps.

Shear stresses within the structure are slightly lower than within the adjacent reaches (see Table 15). Boundary shear stress is dependent on hydraulic radius, and with increased roughness at the adjacent reaches due to the inclusion of LWM, flow depths are higher and consequently the bed shear stresses are higher at these locations. These results support the selection of streambed material, as well as the meander bar material for the design within the streambed. Flows are usually constrained within the channel at the adjacent reaches of the structure for lower flows (e.g., 2-year flow). For higher flows (100-year and above), overbank flows are shallow and have lower velocities (see Table 15 and Figure 64).

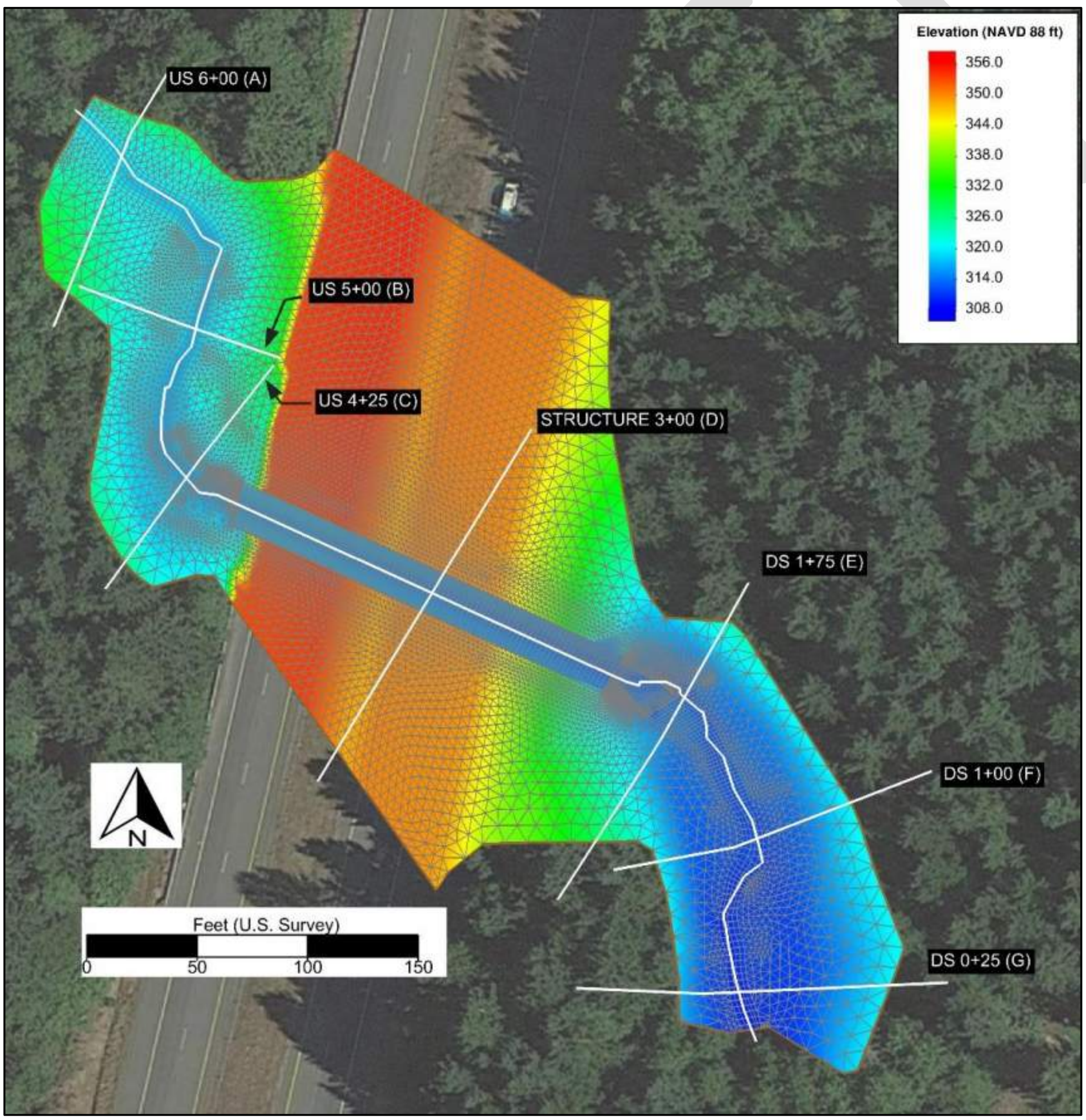


Figure 61: Locations of cross-sections on proposed alignment used for results reporting

Table 14: Average main channel hydraulic results for proposed conditions

Hydraulic parameter	Cross-section	2-year	100-year	Projected 2080 100-year	500-year
Average WSE (feet)	US STA 6+00 (A)	319.0	319.7	320.1	320.0
	US STA 5+00 (B)	317.7	318.5	318.9	318.7
	US STA 4+25 (C)	317.0	317.8	318.2	318.0
	STRUCTURE STA 3+00 (D)	315.0	315.7	316.1	315.9
	DS STA 1+75 (E)	313.7	314.4	314.8	314.6
	DS STA 1+00 (F)	311.9	312.2	312.4	312.3
	DS STA 0+25 (G)	310.9	311.2	311.5	311.4
Maximum depth (feet)	US STA 6+00 (A)	0.8	1.5	1.9	1.8
	US STA 5+00 (B)	1.4	2.2	2.7	2.5
	US STA 4+25 (C)	1.3	2.1	2.5	2.3
	STRUCTURE STA 3+00 (D)	1.0	1.7	2.0	1.9
	DS STA 1+75 (E)	1.2	1.9	2.3	2.1
	DS STA 1+00 (F)	0.7	1.0	1.2	1.1
	DS STA 0+25 (G)	1.0	1.7	2.0	1.9
Average velocity (fps)	US STA 6+00 (A)	3.2	4.4	5.3	4.8
	US STA 5+00 (B)	2.5	5.0	6.1	5.7
	US STA 4+25 (C)	1.7	2.9	3.1	3.0
	STRUCTURE STA 3+00 (D)	3.0	4.9	5.5	5.2
	DS STA 1+75 (E)	2.0	3.2	3.6	3.4
	DS STA 1+00 (F)	3.1	5.1	5.9	5.5
	DS STA 0+25 (G)	1.6	2.8	3.4	3.1
Average shear (pounds per square foot)	US STA 6+00 (A)	0.6	0.9	1.0	0.9
	US STA 5+00 (B)	0.3	0.7	0.9	0.8
	US STA 4+25 (C)	0.6	1.0	1.1	1.1
	STRUCTURE STA 3+00 (D)	0.5	1.0	1.1	1.1
	DS STA 1+75 (E)	0.9	1.3	1.6	1.5
	DS STA 1+00 (F)	0.5	1.0	1.2	1.1
	DS STA 0+25 (G)	0.3	0.5	0.7	0.6

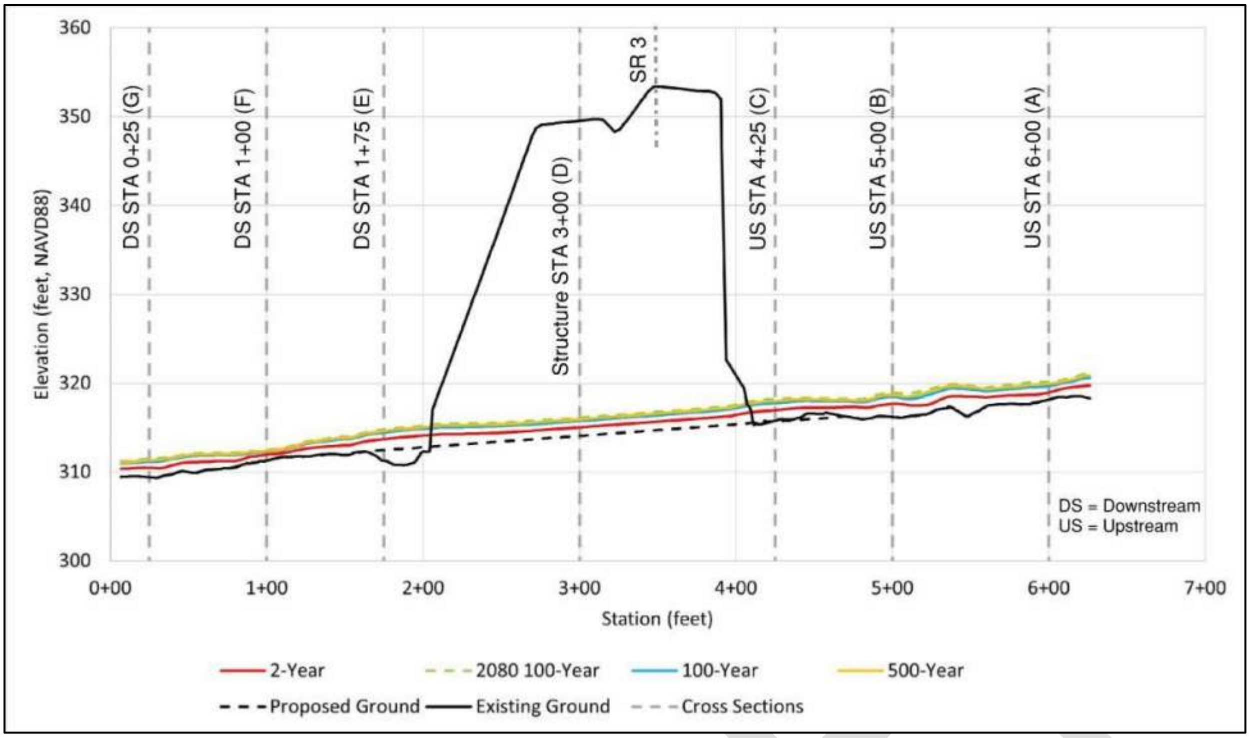


Figure 62: Proposed conditions water surface profiles

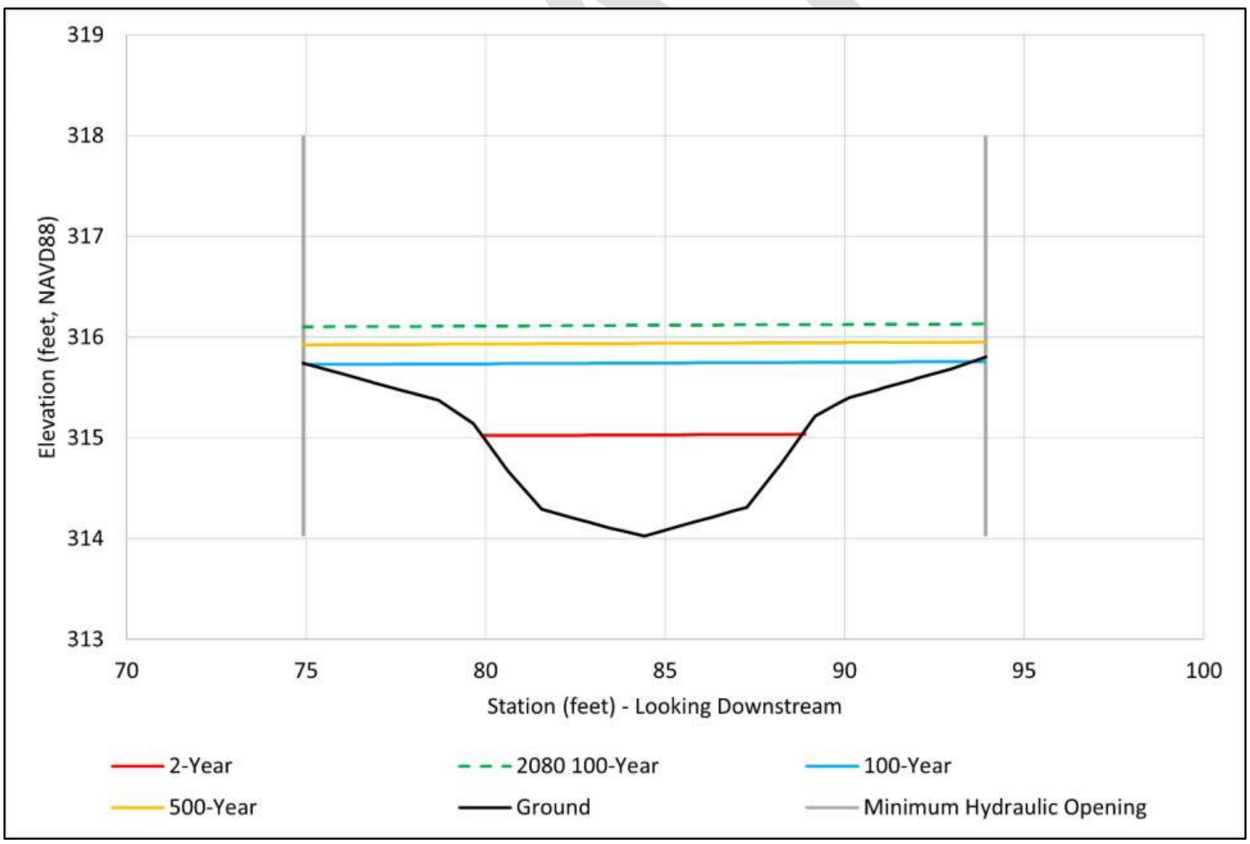


Figure 63: Typical section through proposed structure (STATION 3+00)

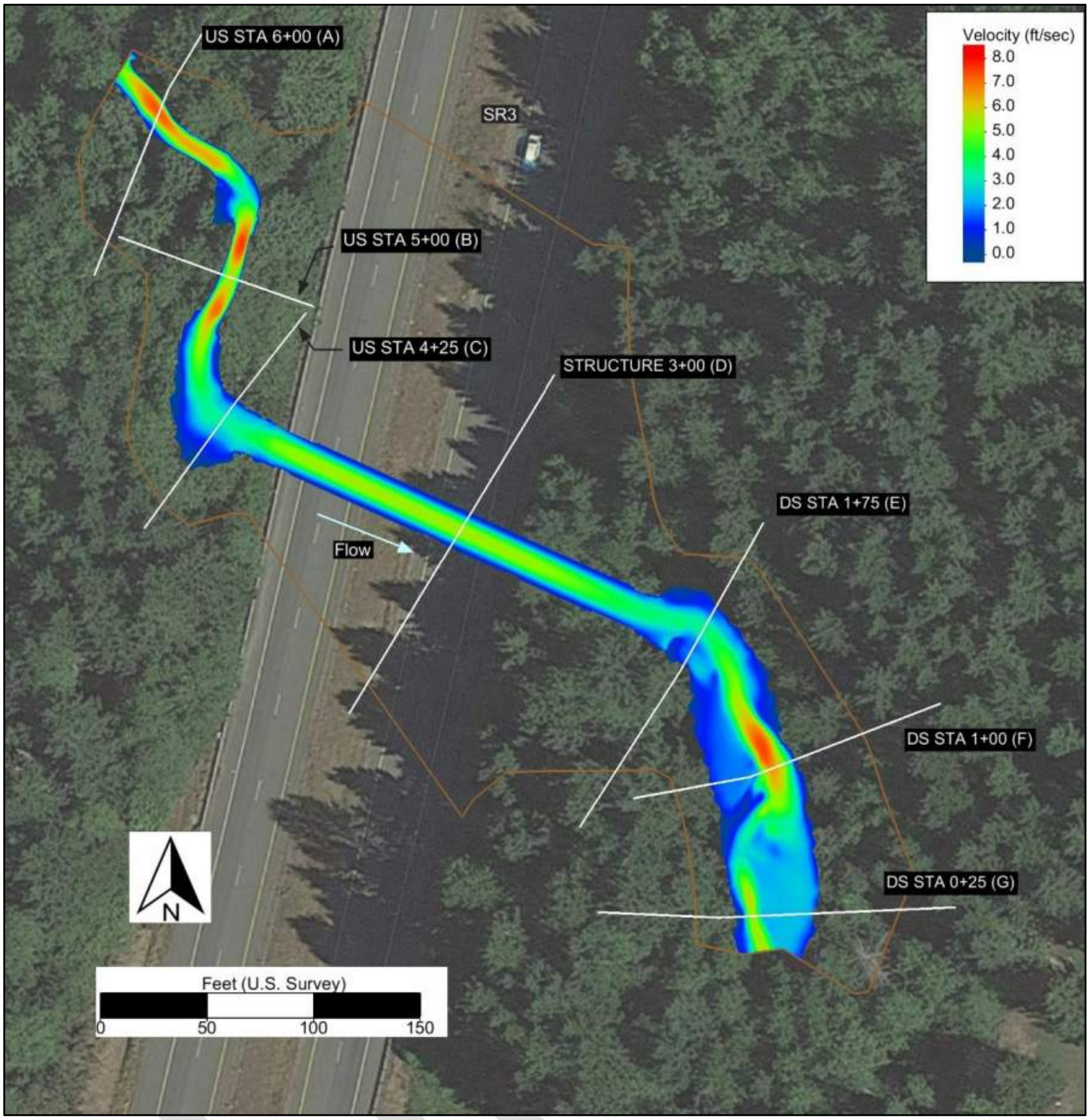


Figure 64: Proposed conditions 100-year velocity map

Table 15: Proposed conditions average channel and floodplains velocities

Cross-section location	Q100 average velocities (fps)			2080 Q100 average velocities (fps)		
	LOB*	Main channel	ROB*	LOB*	Main channel	ROB*
US STA 6+00 (A)	0.0	4.4	0.3	0.0	5.3	0.6
US STA 5+00 (B)	3.7	5.0	3.2	5.2	6.1	4.9
US STA 4+25 (C)	1.6	2.9	0.9	2.1	3.1	1.3
STRUCTURE STA 3+00 (D)	2.4	4.9	2.4	4.1	5.5	3.8
DS STA 1+75 (E)	1.9	3.2	1.3	2.5	3.6	2.2
DS STA 1+00 (F)	2.6	5.1	1.7	3.1	5.9	3.1
DS STA 0+25 (G)	0.0	2.8	1.2	0.0	3.4	2.4

*Left overbank (LOB) and right overbank (ROB) locations were approximated using 2-year water surface widths.

6 Floodplain Evaluation

This project is not within a FEMA special flood hazard area (SFHA); see Appendix A for the FIRM. The existing-project and expected proposed-project conditions were evaluated to determine whether the project would cause a change in flood risk.

6.1 Water Surface Elevations

Water surface elevation changes, using a comparison of existing and proposed conditions for the 100-year event, are limited to the immediate vicinity of the crossing. A storm with a 100-year return period is usually considered the storm of interest in the floodplain when estimating the effects of flooding. With the proposed project, backwater conditions (evident in existing conditions model – See Figure 58) would be eliminated at SR 3, so the water surface immediately upstream of the culvert will decrease due to the proposed crossing (see Figure 65). The WSE immediately downstream of the culvert would increase slightly due to the removal of the drop barrier. With removal of the undersized culvert in existing conditions, this increase is expected. Figure 65 shows the expected change in the water surface profile from existing conditions to proposed conditions. Note that the 100-year existing and proposed surfaces converge at approximately STA 5+80. Figure 66 shows the floodplain areas that will change from dry or wet, along with difference in WSE between the existing and proposed conditions. Because there are no properties or infrastructure near the crossing that would be impacted by a 100-year flood event, it is safe to assume that there are no flood risks to properties or infrastructure.

A flood risk assessment will be developed during later stages of the design.

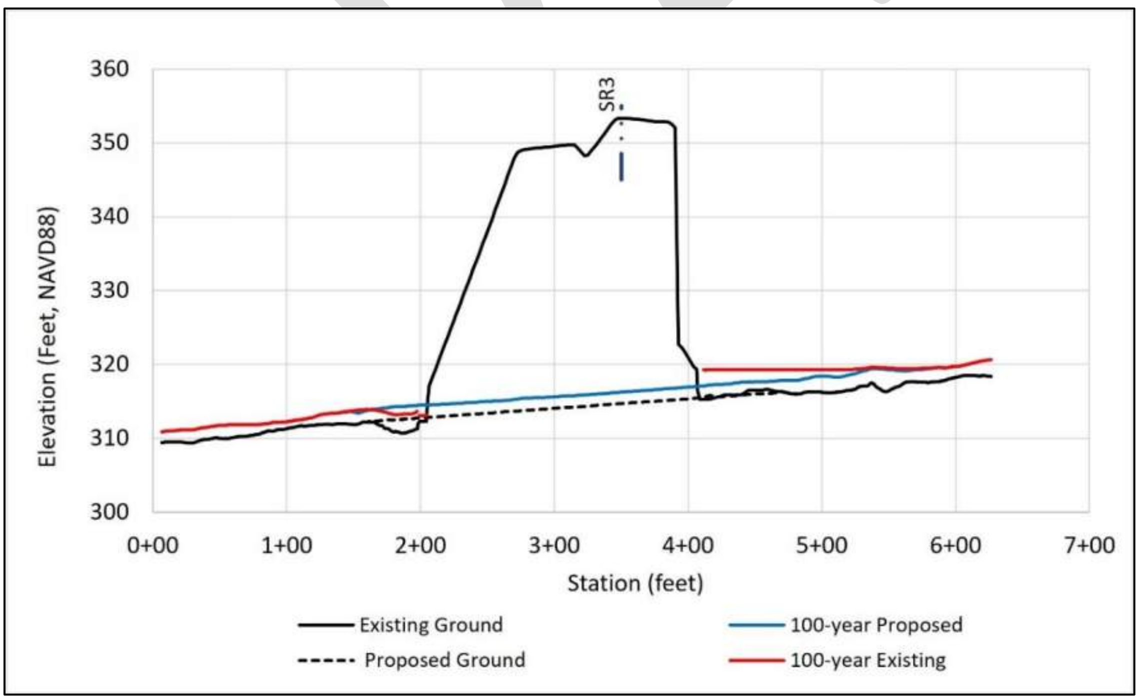


Figure 65: Comparison of 100-year water surface profile for existing conditions and proposed conditions along the proposed alignment

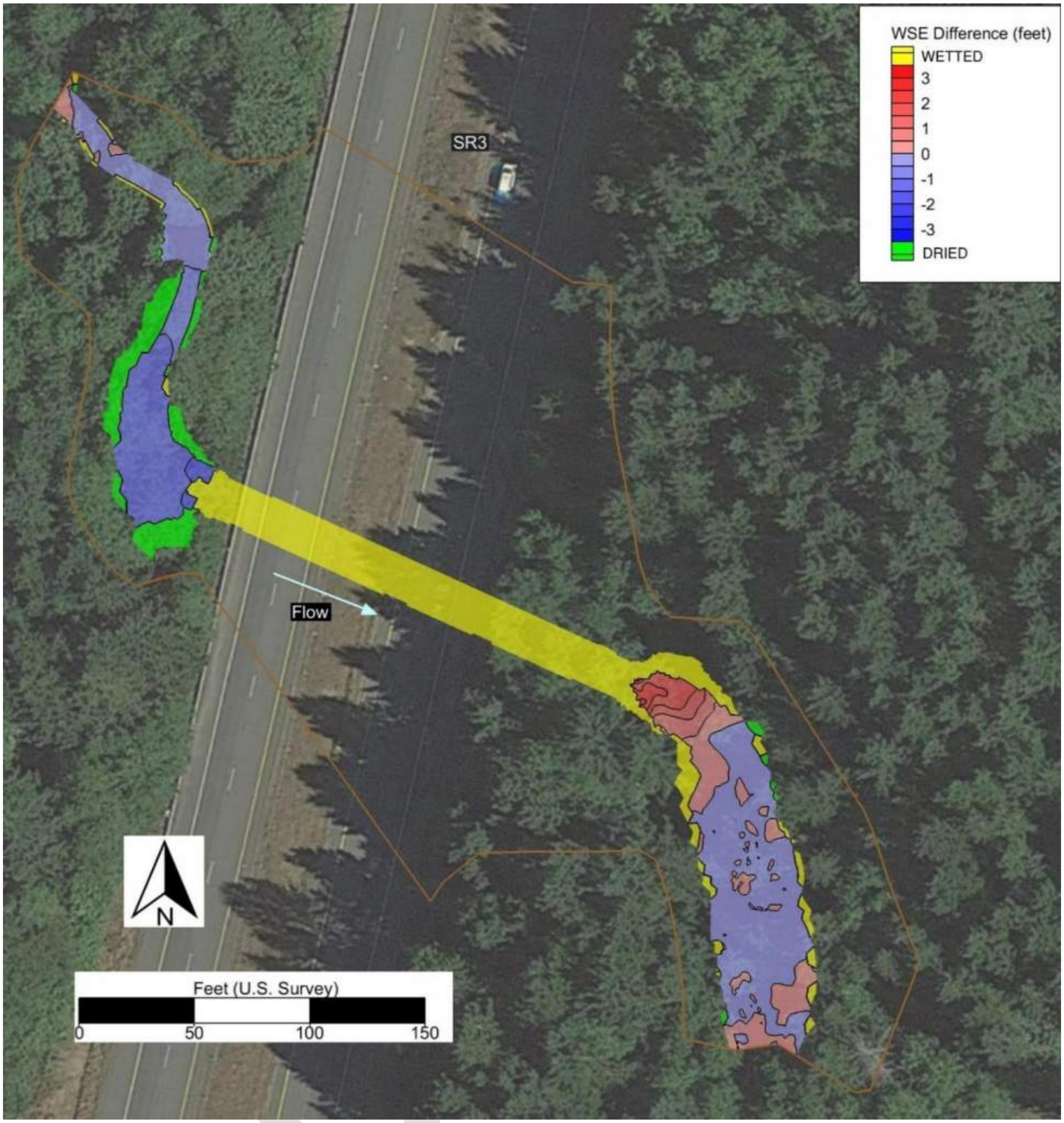


Figure 66: 100-year WSE change from existing conditions to proposed conditions

7 Scour Analysis

Total scour will be computed during later phases of the project using the 100-year, 500-year, and projected 2080 100-year flow events. Design of the proposed structure will account for the potential scour at the projected 2080 100-year flow events. For this preliminary phase of the project, the risk for lateral migration and potential for degradation are evaluated on a conceptual level. This information is considered preliminary and is not to be taken as a final recommendation in either case.

7.1 Lateral Migration

The risk of lateral migration of Big Scandia Creek is undetermined but is potentially low because of the low flows and the confined nature of the channel.

No geotechnical scoping memo or package for preliminary assessment has been performed at this time.

7.2 Long-term Aggradation/Degradation of the Channel Bed

Section 2.7.4 discusses the vertical channel stability. The proposed channel alignment and slope closely mimic the existing conditions, and the potential long-term aggradation in the proposed conditions is minimal. The potential long-term aggradation is up to 1 feet (visual equilibrium projection) in a localized area upstream of the crossing (see the red line in Figure 67), but no long-term aggradation or degradation is anticipated through the crossing. Long-term degradation and aggradation will be quantified with the Final Hydraulic Design Report.

The geotechnical scoping memo or package from WSDOT was not available during the writing of this report and will be included in the next phase of the project.

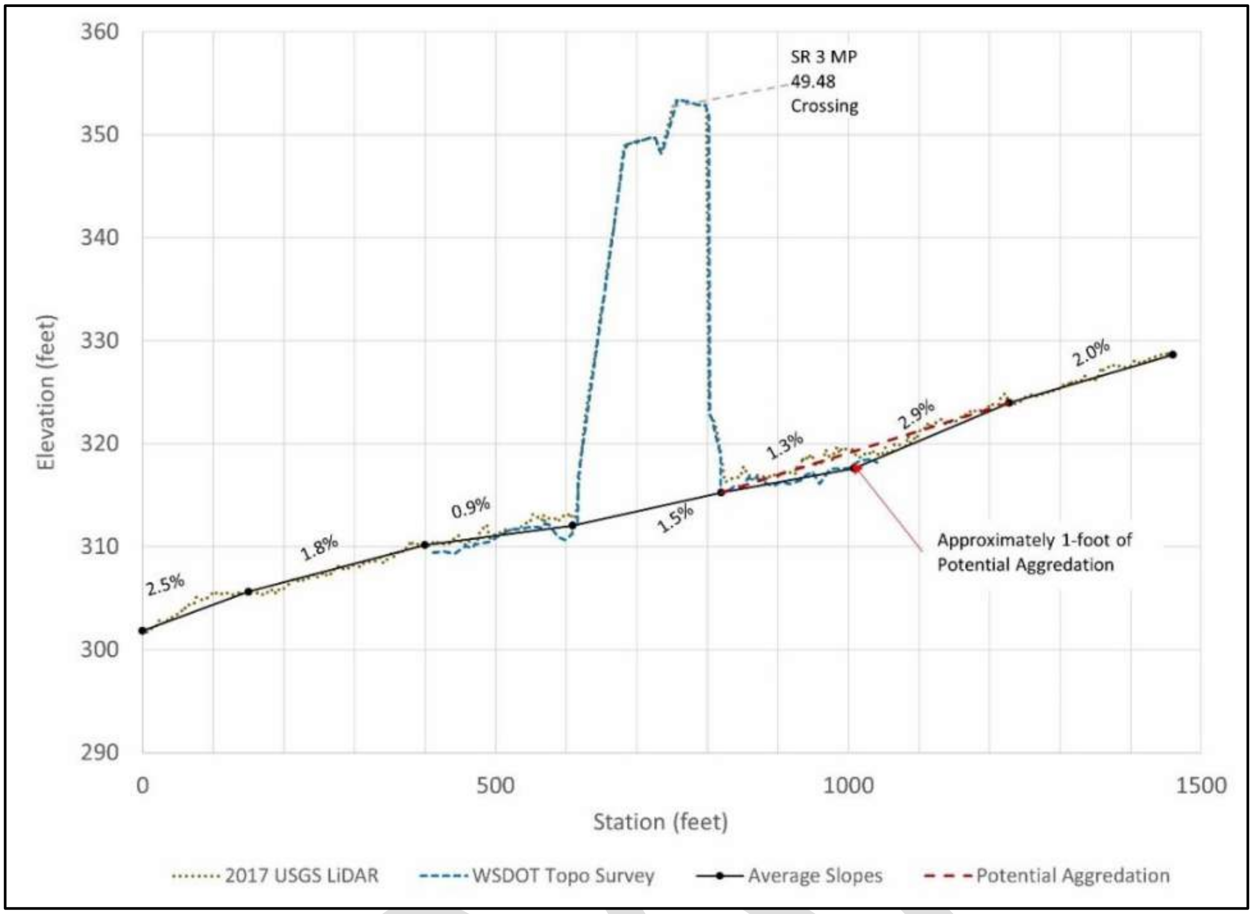


Figure 67: Potential long-term aggradation at the proposed structure upstream face

8 Scour Countermeasures

The need for scour countermeasures has not yet been determined. If scour countermeasures are needed, they will not encroach within the minimum hydraulic opening.

9 Summary

Table 16 presents a summary of the results of this Preliminary Hydraulic Design Report.

Table 16: Report summary

Stream crossing category	Element	Value	Report location
Habitat gain	Total length	6,312 linear feet	2.1 Site Description
Bankfull width (BFW)	Reference reach found?	Yes	2.7.1 Reference Reach Selection
	Design BFW	10 feet	2.7.2 Channel Geometry
	Concurrence BFW	10 feet	2.7.2 Channel Geometry
Floodplain utilization ratio (FUR)	Flood-prone width	17.5 feet	2.7.2.1 Floodplain Utilization Ratio
	Average FUR	2.9	2.7.2.1 Floodplain Utilization Ratio
Channel morphology	Existing	See link	2.7.2 Channel Geometry
	Proposed	See link	4.3.2 Channel Complexity
Hydrology/design flows	100-year flow	69 cfs	3 Hydrology and Peak Flow Estimates
	2080 100-year flow	112 cfs	3 Hydrology and Peak Flow Estimates
	2080 100-year used for design	Yes	3 Hydrology and Peak Flow Estimates
	Dry channel in summer	Yes	3 Hydrology and Peak Flow Estimates
Channel geometry	Existing	See link	2.7.2 Channel Geometry
	Proposed	See link	4.1.1 Channel Planform and Shape
Channel slope/gradient	Existing culvert	1.5%	2.6.2 Existing Conditions
	Reference reach	1.3%	2.7.1 Reference Reach Selection
	Proposed	1.3%	4.1.3 Channel Gradient
Hydraulic width	Existing	4.5 feet	2.6.2 Existing Conditions
	Proposed	19 feet	4.2.2 Hydraulic Width
	Added for climate resilience	No	4.2.2 Hydraulic Width
Vertical clearance	Required freeboard	2 feet	4.2.3 Vertical Clearance
	Required freeboard applied to 100-year or 2080 100-year	2.5 feet	4.2.3 Vertical Clearance
	Maintenance clearance	Recommended 6 feet	4.2.3 Vertical Clearance
	Low chord elevation	See link	4.2.3 Vertical Clearance
Crossing length	Existing	202.5 feet	2.6.2 Existing Conditions
	Proposed	201 feet	4.2.4 Hydraulic Length
Structure type	Recommendation	No	4.2.6 Structure Type
	Type		4.2.6 Structure Type
Substrate	Existing	See link	2.7.3 Sediment
	Proposed	See link	4.3.1 Bed Material
	Coarser than existing?	No	4.3.1 Bed Material

Stream crossing category	Element	Value	Report location
Channel complexity	LWM for bank stability	No	4.3.2 Channel Complexity
	LWM for habitat	Yes	4.3.2 Channel Complexity
	LWM within structure	No	4.3.2 Channel Complexity
	Meander bars	20	4.3.2 Channel Complexity
	Boulder clusters	0	4.3.2 Channel Complexity
	Coarse bands	0	4.3.2 Channel Complexity
	Mobile wood	Yes	4.3.2 Channel Complexity
Floodplain continuity	FEMA mapped floodplain	No	6 Floodplain Evaluation
	Lateral migration	No	2.7.5 Channel Migration
	Floodplain changes?	Yes	6 Floodplain Evaluation
Scour	Analysis	See link	7 Scour Analysis
	Scour countermeasures	Determined at FHD	8 Scour Countermeasures
Channel degradation	Potential?	1 foot aggradation upstream	7.2 Long-term Aggradation/Degradation of the Channel Bed
Channel degradation	Allowed?	Yes	7.2 Long-term Aggradation/Degradation of the Channel Bed

References

Aquaveo. 2021. SMS Version 13.1.15.

Barnard, R.J., J. Johnson, P. Brooks, K.M. Bates, B. Heiner, J.P. Klavas, D.C. Ponder, P.D. Smith, and P.D. Powers. 2013. *Water Crossing Design Guidelines*. Washington State Department of Fish and Wildlife. Olympia, Washington.

Chow, V.T. 1959. Open Channel Hydraulics, McGraw-Hill Book Company, New York.

Dewitz, J. (2021). National Land Cover Database (NLCD) 2019 Products [Data set]. U.S. Geological Survey. https://doi.org/10.5066/P9KZCM54

DNR Geology Portal. 2022. Washington State Department of Natural Resources Geologic Information Portal: https://geologyportal.dnr.wa.gov/2d-view#wigm?-13667520,-13649176,6055258,6065358?Surface_Geology,24k_Surface_Geology,Geologic_Units_24K. Accessed on April 8, 2022.

Fox, Martin and Bolton, Susan. 2007. *A Regional and Geomorphic Reference for Quantities and Volumes of Instream Wood in Unmanaged Forests Basins of Washington Stat. North American Journal of Fisheries Management.* Vol. 27, Issue 1, pp. 342–359.

FPDSI, 2021. Fish Passage and Diversion Screening Inventory Database. http://apps.wdfw.wa.gov/fishpassagephotos/Reports/996804_Report.pdf Accessed on Dec 4, 2021

Google Earth. 2021. Imagery date: 06/19/2021, Location: 47°42’24.30” N, 122°38’43.91”W. Version Google Earth Pro 7.3.4.8248.

Haugerud, Ralph A., 2009, Preliminary geomorphic map of the Kitsap Peninsula, Washington: U.S. Geological Survey, Open-File Report 2009-1033, 2 sheets, scale 1:36,000 [https://pubs.usgs.gov/of/2009/1033/].

Porter, S.C., and Swanson, T.W. 1998. Radiocarbon age constraints on rates of advance and retreat of the Puget Lobe of the Cordilleran Ice Sheet during the last glaciation: Quaternary Research, v. 50, pp. 205-213.

PRISM Climate Group, 2021. Oregon State University, https://prism.oregonstate.edu, accessed 05 Dec 2021.

USBR (United States Bureau of Reclamation). 2017. SRH-2D Version 13.1.14.

USDA (United States Department of Agriculture). 2008. *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings, Appendix E.*

USDA NRCS (Natural Resources Conservation Service). 2021. Natural Resources Conservation Service Soil Survey Geographic Database. Accessed July 2021.

USGS (United States Geological Survey). 2016. The StreamStats program, online at: http://streamstats.usgs.gov. Accessed on December 8, 2021.

Washington State Department of Natural Resources (WSDNR) Washington LiDAR Portal. 2018. Available online at: https://lidarportal.dnr.wa.gov/. Accessed on November 15, 2021.

WDFW (Washington Department of Fishes and Wildlife) 2021. Available online at: https://geo.wa.gov/datasets/wdfw::statewide-washington-integrated-fish-distribution/explore?location=47.717863%2C-122.661126%2C13.66 . Accessed on Dec 06, 2021

WSDOT (Washington State Department of Transportation). 2020. Chronic Environmental Deficiency 2020 Annual Report. WSDOT Environmental Services and Hydraulics Office.

WSDOT (Washington State Department of Transportation). 2022. *Draft Hydraulics Manual*. Olympia, Washington. Publication M 23-03.06.

Appendices

Appendix A: FEMA Floodplain Map

Appendix B: Hydraulic Field Report Form

Appendix C: Streambed Material Sizing Calculations

Appendix D: Stream Plan Sheets, Profile, Details

Appendix E: Manning's Calculations

Appendix F: Large Woody Material Calculations

Appendix G: Future Projections for Climate-Adapted Culvert Design

Appendix H: SRH-2D Model Results

Appendix I: SRH-2D Model Stability and Continuity

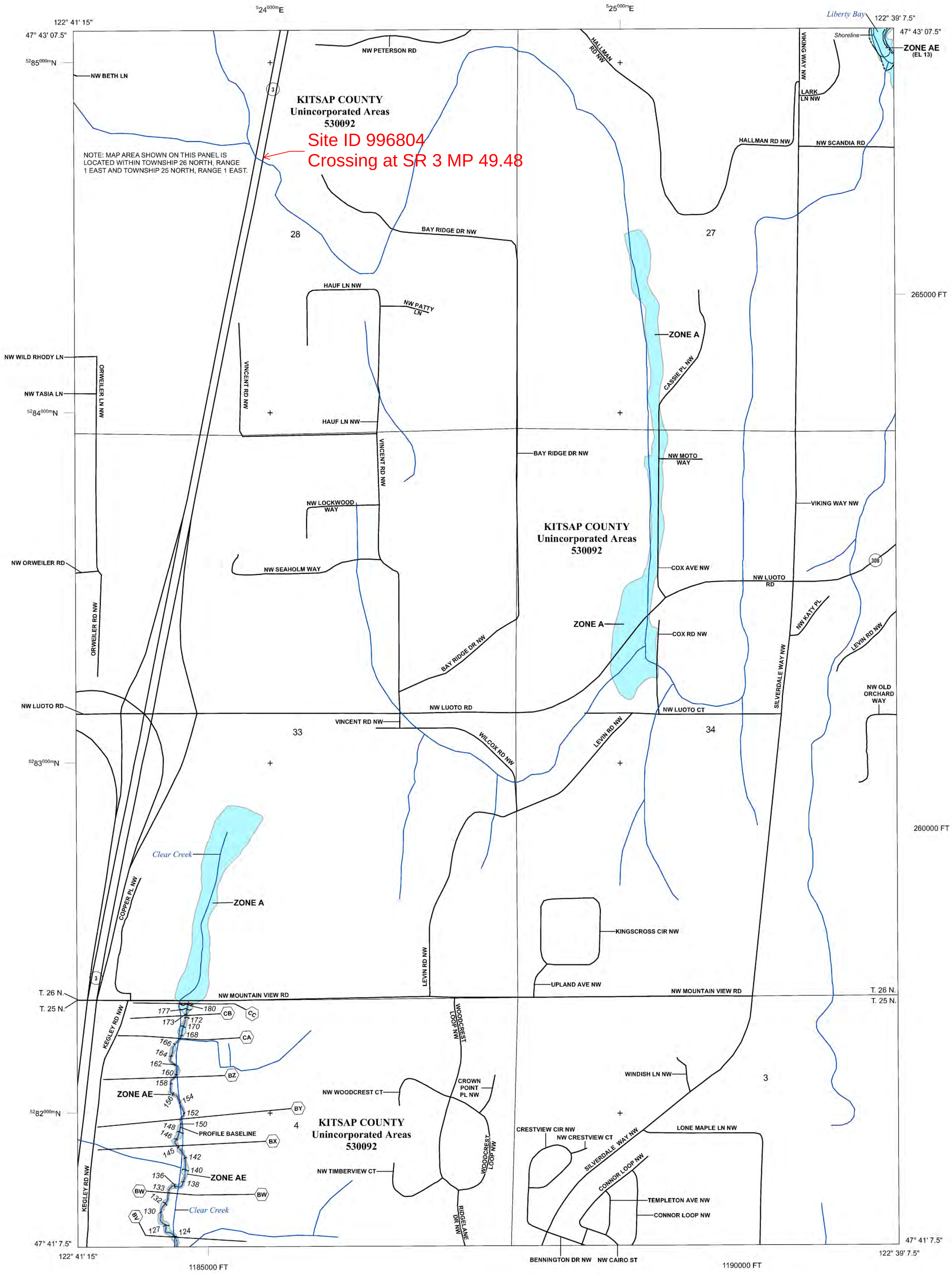
Appendix J: Reach Assessment

Appendix K: Scour Calculations (To be included in next review)

Appendix L: Floodplain Analysis (To be completed later)

This page intentionally blank

Appendix A: FEMA Floodplain Map



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR ZONE DESCRIPTIONS AND INDEX MAP

THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT
HTTP://MSC.FEMA.GOV

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A, V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee See Notes. *Zone X*
OTHER AREAS	NO SCREEN Areas Determined to be Outside the 0.2% Annual Chance Floodplain *Zone X*
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer
	Accredited or Provisionally Accredited Levee, Dike, or Floodwall
	Non-accredited Levee, Dike, or Floodwall
	E 18.2 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation (BFE)
	8 Coastal Transect
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
	513 Base Flood Elevation Line (BFE)
OTHER FEATURES	Limit of Study
	Jurisdiction Boundary

NOTES TO USERS

For information and questions about this map, available products associated with this FIRM including historic versions of this FIRM, how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1-877-336-2627) or visit the FEMA Map Service Center website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website. Users may determine the current map date for each FIRM panel by visiting the FEMA Map Service Center website or by calling the FEMA Map Information eXchange.

Communities annexing land on adjacent FIRM panels must obtain a current copy of the adjacent panel as well as the current FIRM Index. These may be ordered directly from the Map Service Center at the number listed above.

For community and countywide map dates refer to the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in the community, contact your Insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

Base map information shown on this FIRM was provided in digital format by Washington State GIS, Kitsap County GIS and Kitsap County Auditor and Elections.

SCALE

N

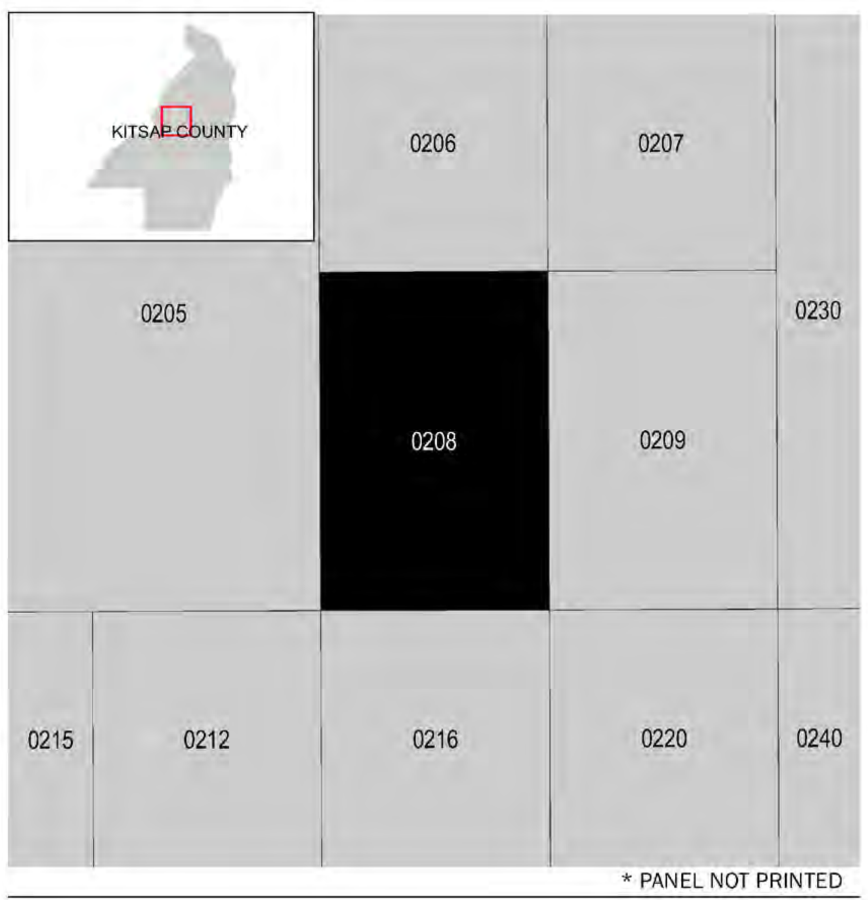
Map Projection:
NAD 1983 UTM Zone 10N;
Western Hemisphere; Vertical Datum: NAVD 88

1 inch = 500 feet 1:6,000

0 500 1,000 2,000 Feet

0 125 250 500 Meters

PANEL LOCATOR



* PANEL NOT PRINTED

FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP

KITSAP COUNTY, WASHINGTON
AND INCORPORATED AREAS

PANEL **208** OF **525**

FEMA

Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
KITSAP COUNTY	530092	0208	F

VERSION NUMBER
2.2.2.1

MAP NUMBER
53035C0208F

MAP REVISED
FEBRUARY 3, 2017

Appendix B: Hydraulic Field Report Form

WSDOT Hydraulics Section	Hydraulics Field Report	Project Number: Y-12554-Task Order AC
	Project Name: Olympic Region GEC	Date: 12/01/2021
	Project Office: WSDOT HQ Hydraulics office – Olympic Region	Time of Arrival: 2:00 pm
	Stream Name: Big Scandia Creek	Time of Departure: 3:30 pm
WDFW ID Number: 996804	Tributary to: Liberty Bay	Weather: Sunny, 50° F
State Route/MP: SR 3 MP 49.48	Township/Range/Section/ ¼ Section: Township 26 North, Range 01 East, Section 28	Prepared By: Sulochan Dhungel
County: Kitsap	Purpose of Site Visit: Site Visit 2 – Stream Assessment, Project Constraints	WRIA: 15

Meeting Location:

Attendance List:

Name	Organization	Role
Sulochan Dhungel	David Evans and Associates, Inc.	Lead PHD author
Micco Emeson	David Evans and Associates, Inc.	Junior Engineer
Josh Owens	David Evans and Associates, Inc.	Geomorphologist
Gray Rand	David Evans and Associates, Inc.	Senior Biologist
Bryan Darby	David Evans and Associates, Inc.	Biologist

Bankfull Width:

Four bankfull width (BFW) measurements were taken within the reference reach (BFW-5, BFW-6, BFW-7, and BFW-8), located upstream of the existing culvert. The average of these measurements is 10 feet. Four additional bankfull widths on the downstream side of the existing culvert were also measured. See Figure 1 for bankfull width measurement locations.

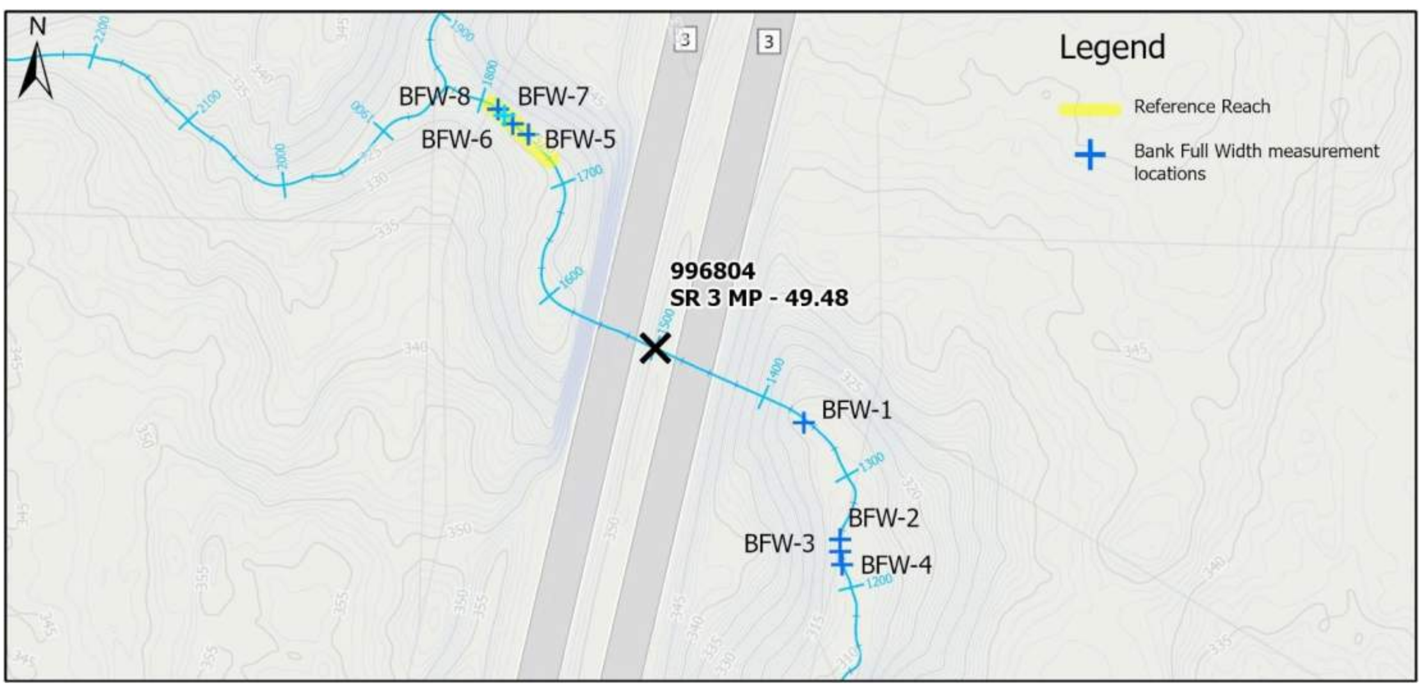


Figure 1 Bankfull width measurement locations

BFW-1 was measured about 100 feet downstream of the culvert opening (Figure 2). The measured BFW was 6 feet. This section of stream had a lot of small debris and flow seemed to be significantly influenced by the existing culvert.

Figure 2 BFW-1 measurement

BFW-2 was measured approximately 140 feet downstream of the culvert opening (Figure 3). Measured BFW was 7.5 feet.

Figure 3 BFW-2 measurement

BFW-3 was measured approximately 155 feet downstream of the culvert opening (Figure 4). Measured BFW was 7.5 feet.

Figure 4 BFW-3 measurement

BFW-4 was measured approximately 170 feet downstream of the culvert opening (Figure 5). Measured BFW was 7.5 feet.

Figure 5 BFW-4 measurement

The following bankfull width measurements were taken within the reference upstream of the culvert. BFW-5 was measured within the reference reach about 180 feet upstream of the culvert opening (Figure 6). Measured BFW was 8 feet.

Figure 6 BFW-5 measurement

BFW-6 was measured within the reference reach about 200 feet upstream of the culvert opening (Figure 7). Measured BFW was 12 feet.

Figure 7 BFW-6 measurement

BFW-7 was measured within the reference reach about 210 feet upstream of the culvert opening (Figure 8). Measured BFW was 12 feet.


Figure 8 BFW-7 measurement

BFW-8 was measured within the reference reach about 220 feet upstream of the culvert opening (Figure 9). Measured BFW was 8 feet.


Figure 9 BFW-8 measurement

Reference Reach:

The reference reach is a 100-feet segment that begins approximately 125 feet upstream of culvert inlet, extending to approximately 225 feet upstream of culvert inlet. At the culvert outlet the channel morphology appears to be influenced by vegetation that consists of red alder and salmonberry resulting in a shallow channel with a channel bed consisting of fine material and organic matter (Figure 10). Red alder and salmonberry are common in areas that have undergone disturbance creating high light conditions, therefore this vegetation is likely present due to the ground disturbance created during construction of the highway and the reference reach was selected in a location where the vegetation transitioned to include cedars and ferns and the channel was better defined. (Figure 11).

Figure 10 Upstream of culvert looking towards culvert inlet and highway, vegetation is dominated by salmonberry and red alder.

Figure 11 Vegetation in the reference reach includes cedars and ferns in addition to salmonberry and alder

The reference reach channel ranged in depth from 0.5 feet to 1.5 feet at the time of the site visit. The banks in the reference reach consisted of cohesive soils, the left bank is confined by a hillslope and does not have an overbank. The right bank has an overbank that is accessible during high flows. The channel bed consisted of sands and gravels with some locations with fines and organic matter.

Upstream of the reference reach the vegetation transitions to alder and salmonberry (Figure 12) and the channel becomes shallower and narrower, similar to the channel section directly upstream of the culvert.

Figure 12 Upstream end of reference reach looking upstream, note that upstream of reference reach the vegetation transitions to being dominated by salmonberry and alder .

Data Collection:

Data was collected by staff engineers from David Evans and Associates, Inc. on Dec 1st, 2021. The field crew included the lead author for the PHD at this site, a junior engineer, a geomorphologist and two aquatic biology experts. The downstream end of the site was visited first. Observations were recorded, including two pebble counts and four bankfull width measurements. The natural conditions of the downstream reflected an appropriate reference reach. Next, the upstream side of the culvert was visited and a single pebble count with four more bankfull width measurements were made.

Observations:

Describe site conditions, channel geomorphology, habitat type and location, flow splits, LWM location and quantity, etc.

The site visit occurred during winter baseflow conditions. The culvert inlet had some debris but did not have any blockage. The culvert outlet flows into a large pool immediately downstream of the outlet. The culvert was installed at a mild slope and does not appear to significantly limit water or sediment capacity. Metal culvert aprons are present at the upstream and downstream ends of the culvert, at the downstream end material has been washed out below the floor of the apron.

The channel slope is mild and visually estimated to be less than 0.5%. The channel morphology shows two distinct characteristics depending on the type of vegetation present. Alder and salmonberry are present downstream of the culvert for the 200 feet that was visited and extended further downstream. In this vegetation the channel is straight, shallow and has low banks. There is little channel capacity above the baseflow that was observed, and high flows readily access the overbanks resulting in a channel bed that is dominated by fines and organic matter. There are regular debris build-ups that span the channel creating drops on the order of 1 to 2 inches (Figure 13). This vegetation is likely the result of prior disturbance and this morphology is also present for about 100 feet upstream of the culvert and upstream of the reference reach.

Figure 13 Typical channel morphology with alder and salmonberry vegetation

In the reference reach upstream of the culvert the vegetation consists of cedar and ferns at the right bank with an accessible overbank, and salmonberry on the left bank that is a confining hillslope. The channel is deeper with coarser bed material and a channel bend influenced by the presence of a cedar tree (Figure 11). The bank is steep and about 4 to 6 inches above the water surface, indicating that it is accessible during high flows. The ferns provide some shade at the edge of the channel. The cedars provide more shade in the reference reach.

The culvert is approximately 200 feet long and is under a four-lane highway with a divided median. The downstream end of the culvert (east side of highway) has a fill slope embankment, and the upstream end of the culvert (west side of highway) is supported by a retaining wall (Figure 14) that is approximately 30 feet tall.

Figure 14 A 30-feet wall supporting the fill material above the culvert on the upstream side.

Pebble Counts:

Three Wolman Pebble counts (PC) were conducted at this site. See Figure 15 for pebble count locations.

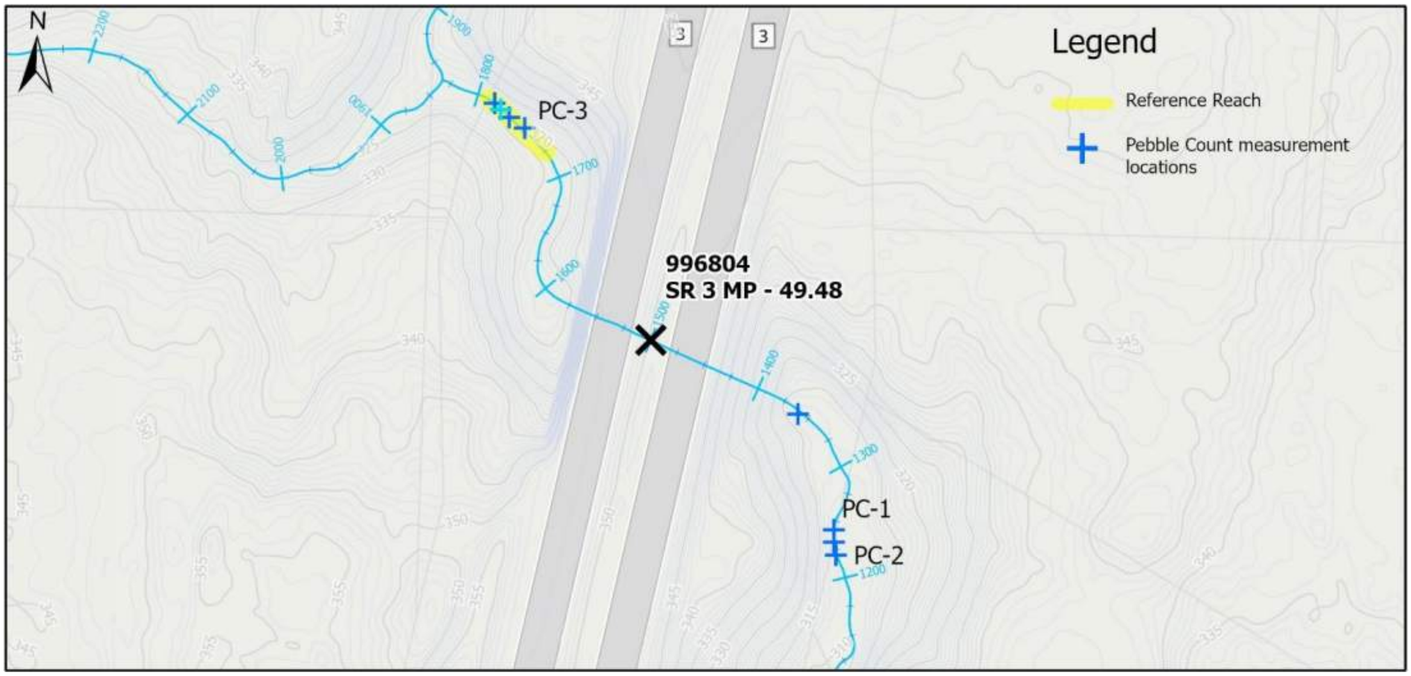


Figure 15 Pebble count Locations

PC-1 was conducted along a length of stream approximately 135 feet downstream of the existing culvert outlet and PC-2 was conducted along the length of stream approximately 150 feet downstream of the existing culvert outlet on the reference reach. Most of the channel consisted of fines and organic matter, but there were local areas with sands and gravels that could be characterized with a pebble count. Therefore, the two pebble counts represent about 20% of the total reach with the remaining of the reach being fines. See Figure 16 for approximate sediment dimensions and distribution at site PC-1. See Figure 17 for approximate sediment dimensions and distributions at site PC-2. These pebble counts represent the coarser material that is present and can be mobilized if the channel were to be more channelized similar to the reference reach.

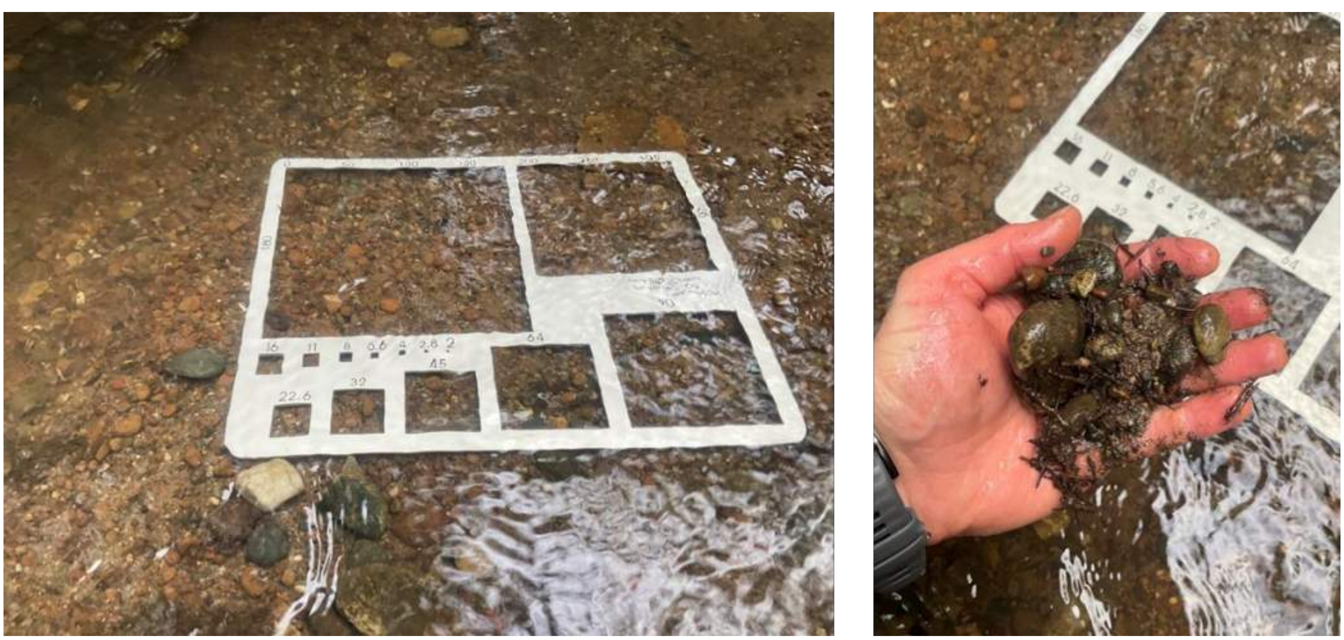


Figure 16 PC-1 location: sediment w/ gravelometer and sediment in hand

Figure 17 PC-2 location: sediment w/ gravelometer and sediment in Hand

PC-3 was conducted along the length of stream approximately 240 feet upstream of the existing culvert inlet within the reference reach. The sediment here consisted of a generally sand sediments with some coarser materials. See Figure 18 for approximate sediment dimensions and distributions at site PC-3.

Figure 18 PC-3 location: sediment w/ gravelometer and sediment in hand

Photos:

Samples:	
Work within the wetted perimeter may only occur during the time periods authorized in the APP ID 21036 entitled "Allowable Freshwater Work Times May 2018". Work outside of the wetted perimeter may occur year-round. APPS website: https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Shared/Pages/Main/Login.aspx	
Were any sample(s) collected from below the OHWM?	*No ☐ If no, then stop here.*
	Yes ☒ If yes, then fill out the proceeding section for each sample.

Sample #:	Work Start:	Work End:	Latitude:	Longitude:
PC-1, PC-2 and PC-3	Dec 1, 2021 2:00 PM	Dec 1, 2021 3:00 PM	47.715416	-122.68019

Summary/description of location:

Three Wolman Pebble Count (PC) were taken at this location. Two PCs were conducted downstream of the culvert outlet, one approximately 130 feet and one 150 feet downstream of culvert outlet. Another PC was conducted approximately 330 feet upstream of culvert inlet.

Description of work below the OHWL:

Work within the OHW included Wolman Pebble Counts which consists of walking along the streambed to collect 100 random samples of sediment. These samples are then measured in-situ to determine the gradation of the existing streambed sediment. After being measured the samples are returned to the stream.

Description of problems encountered:

No problems were encountered.

Concurrence Meeting	Date: Feb 3, 2022	Time of Arrival: 12:00 PM
Prepared By: Mike Rice	Weather: Clear	Time of Departure: 2:00 PM

Attendance List:

Name	**Organization**	**Role**
Mike Rice	David Evans and Associates, Inc.	Senior Engineer
Micco Emeson	David Evans and Associates, Inc.	Junior Engineer
Heather Pittman	WSDOT	Hydraulic Engineer
Damon Romero	WSDOT	Fish Passage Coordinator
Cade Roler	WSDOT	Engineer
Amber Martens	WDFW	Biologist
Alison O' Sullivan	Suquamish Tribe	Tribal representative

Bankfull Width:

Two bank-full widths were measured in the reference reach. Both measurements showed that the BFW was 8 feet wide.

Figure 19: Bank-full width measurement within reference reach.

Reference Reach:

There was concurrence on the selection of reference reach among all parties.

Observations:

*A recent high flow event had accumulated lots of small debris along the top of the bank (*Figure 20*).*

Figure 20: Accumulation of small debris along the bank.

The channel material was coarser than during site visit #2 which took place on Dec 2, 2021. It was surmised that the high flow event might have caused this. There were some large gravels that were seen in this site visit, not seen in the previous one (Figure 21).

Figure 21: Coarse and larger sediments were observed not previously seen in earlier site visits.

Based on rough field observations, the channel had dropped about 0.5 to 1-foot in some places. Speculation was made that the culvert might have been blocked upstream and a large flow was released as it became unblocked after a high flow event. These drops caused flows to drop lower than earlier site visits and the banks were much more evident.

Figure 22: Drop in flow elevation and clearly evident banks.

There were lots of mid-sized (6 to 12-inch diameter) woody debris in channel forming small steps 6-12 inches in height. Some of the small debris drops seen in earlier site visits were swept away at some locations (Figure 23).

Figure 23: Woody debris in the channel (LEFT) and Debris drops removed by the high flow event (RIGHT).

Photos:

Figure 24: Trees and vegetation fallen from the recent storm event. The tree on the right was a part of vegetation on the reference reach.

Appendix C: Streambed Material Sizing Calculations

Summary - Stream Simulation Stream Bed Design

Project:	Preliminary Hydraulic Design for Big Scandia Creek at SR3 MP 49.48 (ID 996804)
By:	Sulochan Dhungel, P.E.

Design Gradation:

Location:	StreamBed			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.50	0.18	0.07	0.01
in	6.000	2.216	0.879	0.118
mm	152	56	22.3	3.0

Design Gradation:

Location:	PB3			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.09	0.02	0.00
in	5.040	1.120	0.290	0.003
mm	128	28	7.4	0.1

Design Gradation:

Location:				
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.00	0.00	0.00	0.00
in				
mm	0	0	0.0	0.0

Design Gradation:

Location:				
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.00	0.00	0.00	0.00
in				
mm	0	0	0.0	0.0

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size [in]	[mm]	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}
36.0	914									100	100.0
32.0	813									50	100.0
28.0	711								100		100.0
23.0	584								50		100.0
18.0	457							100			100.0
15.0	381							50			100.0
12.0	305						100				100.0
10.0	254					100	80				100.0
8.0	203				100	80	68				100.0
6.0	152			100	80	68	57				100.0
5.0	127			80	68	57	45				95.0
4.0	102		100	71	57	45	39				92.8
3.0	76.2		80	63	45	38	34				90.6
2.5	63.5	100	65	54	37	32	28				88.4
2.0	50.8	92.5	50	45	29	25	22				80.6
1.5	38.1	79	35	32	21	18	16				67.4
1.0	25.4	66	20	18	13	12	11				54.1
0.50	12.7	48	5	5	5	5	5				37.3
0.19	4.75	29									21.8
0.02	0.425	10									7.5
0.003	0.0750	5									3.8
% per category		75	0	25	0	0	0	0	0	0	--> 100%
% Cobble & Sediment		75.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0%

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

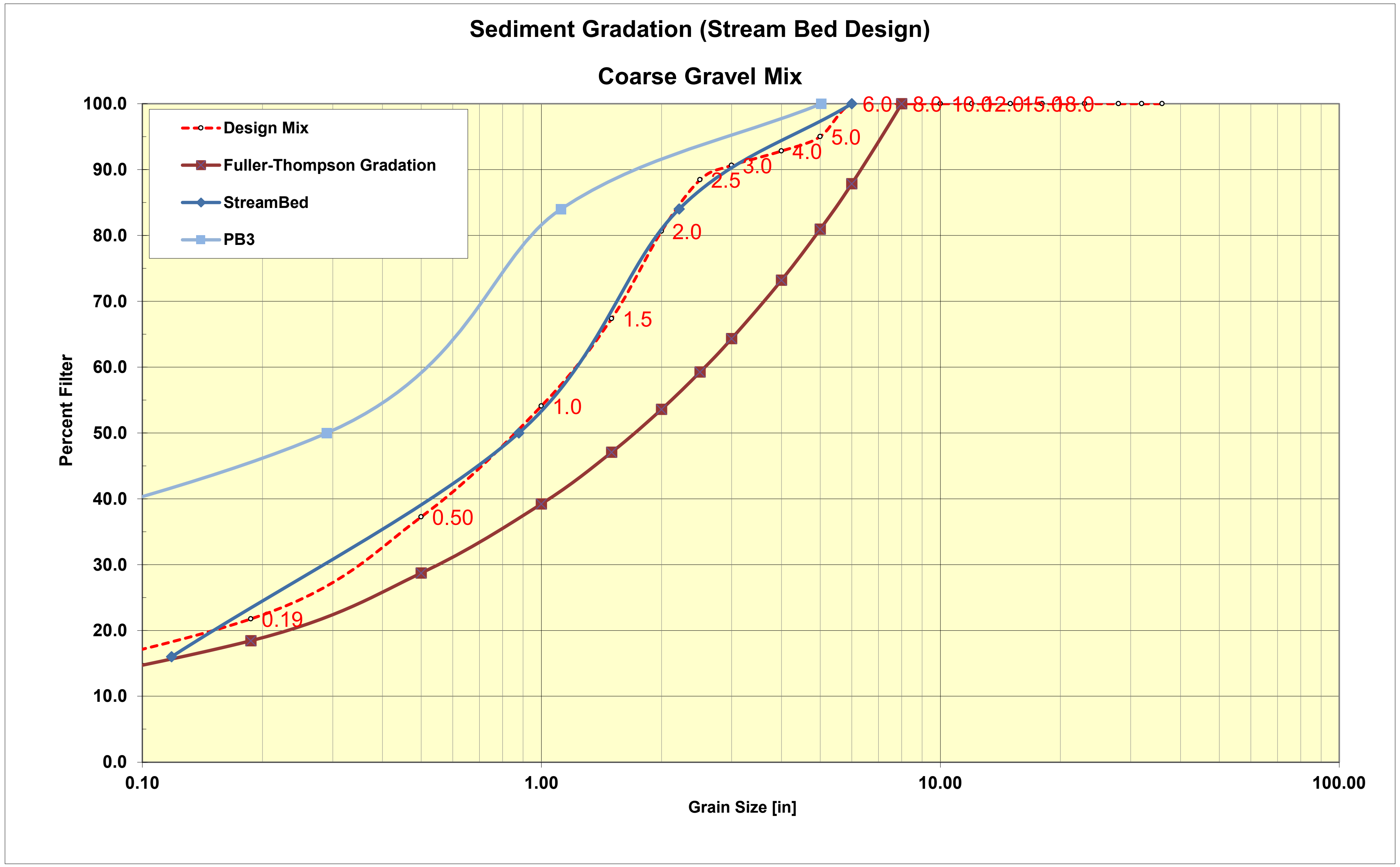
Sand/gravel streams with high relative submergence

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.047	dimensionless Shields parameter for D50, use table E.1 of USFS manual
		or assume 0.045 for poorly sorted channel bed

Flow	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
Average Modeled Shear Stress (lb/ft^2)	0.53	0.76	0.86	0.92	0.97	1.06

τ_{ci}	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
1.08	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.04	No Motion	No Motion	No Motion	No Motion	No Motion	Motion
1.00	No Motion	No Motion	No Motion	No Motion	No Motion	Motion
0.94	No Motion	No Motion	No Motion	No Motion	Motion	Motion
0.87	No Motion	No Motion	No Motion	Motion	Motion	Motion
0.83	No Motion	No Motion	Motion	Motion	Motion	Motion
0.77	No Motion	No Motion	Motion	Motion	Motion	Motion
0.73	No Motion	Motion	Motion	Motion	Motion	Motion
0.68	No Motion	Motion	Motion	Motion	Motion	Motion
0.63	No Motion	Motion	Motion	Motion	Motion	Motion
0.59	No Motion	Motion	Motion	Motion	Motion	Motion
0.56	No Motion	Motion	Motion	Motion	Motion	Motion
0.51	Motion	Motion	Motion	Motion	Motion	Motion
0.48	Motion	Motion	Motion	Motion	Motion	Motion
0.45	Motion	Motion	Motion	Motion	Motion	Motion
0.41	Motion	Motion	Motion	Motion	Motion	Motion
0.37	Motion	Motion	Motion	Motion	Motion	Motion
0.30	Motion	Motion	Motion	Motion	Motion	Motion

D50	0.88	in
	0.07	ft
	22.3	mm



Fuller-Thompson Gradation

Dmax = 8

D[in]	
12.000	120.02
10.000	110.56
8.000	100.00
6.000	87.86
5.000	80.94
4.000	73.20
3.000	64.32
2.500	59.25
2.000	53.59
1.500	47.08
1.000	39.23
0.500	28.72
0.187	18.45
0.017	6.23
0.003	2.85

Summary - Stream Simulation Meander Bar Design

Project:	**Preliminary Hydraulic Design for Big Scandia Creek at SR3 MP 49.48 (ID 996804)**
By:	**Sulochan Dhungel, P.E.**

Design Gradation:				
Location:	Proposed Channel (Meander Bar)			
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.83**	**0.57**	**0.16**	**0.03**
in	**10.000**	**6.857**	**1.892**	**0.317**
mm	**254**	**174**	**48.1**	**8.1**

Design Gradation:				
Location:	PB3			
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.42**	**0.09**	**0.02**	**0.00**
in	**5.040**	**1.120**	**0.290**	**0.003**
mm	**128**	**28**	**7.4**	**0.1**

Design Gradation:				
Location:				
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.00**	**0.00**	**0.00**	**0.00**
in				
mm	**0**	**0**	**0.0**	**0.0**

Design Gradation:				
Location:				
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.00**	**0.00**	**0.00**	**0.00**
in				
mm	**0**	**0**	**0.0**	**0.0**

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size		**Streambed Sediment**	**Streambed Cobbles**					**Streambed Boulders**			**D_{size}**
[in]	**[mm]**		**4"**	**6"**	**8"**	**10"**	**12"**	**12"-18"**	**18"-28"**	**28"-36"**	
36.0	**914**									**100**	**100.0**
32.0	**813**									50	**100.0**
28.0	**711**								**100**		**100.0**
23.0	**584**								50		**100.0**
18.0	**457**							**100**			**100.0**
15.0	**381**							50			**100.0**
12.0	**305**						**100**				**100.0**
10.0	**254**					**100**	**80**				**100.0**
8.0	**203**				**100**	**80**	68				**88.0**
6.0	**152**			**100**	**80**	68	57				**81.0**
5.0	**127**			**80**	68	57	**45**				**74.0**
4.0	**102**		**100**	71	57	**45**	39				**67.0**
3.0	**76.2**		**80**	63	**45**	38	34				**63.0**
2.5	**63.5**	**100**	65	54	37	32	28				**59.0**
2.0	**50.8**	**92.5**	50	**45**	29	25	22				**52.0**
1.5	**38.1**	79	**35**	32	21	18	16				**42.7**
1.0	**25.4**	**66**	20	18	13	12	11				**33.4**
0.50	**12.7**	**48**	**5**	**5**	**5**	**5**	**5**				**22.2**
0.19	**4.75**	29									**11.6**
0.02	**0.425**	**10**									**4.0**
0.003	**0.0750**	**5**									**2.0**
% per category		**40**	**0**	**0**	**0**	**60**	**0**	**0**	**0**	**0**	*--> 100%*
% Cobble & Sediment		**40.0**	**0.0**	**0.0**	**0.0**	**60.0**	**0.0**	**0.0**	**0.0**	**0.0**	*100.0%*

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

uniform bed material (Di < 20-30 times D50)

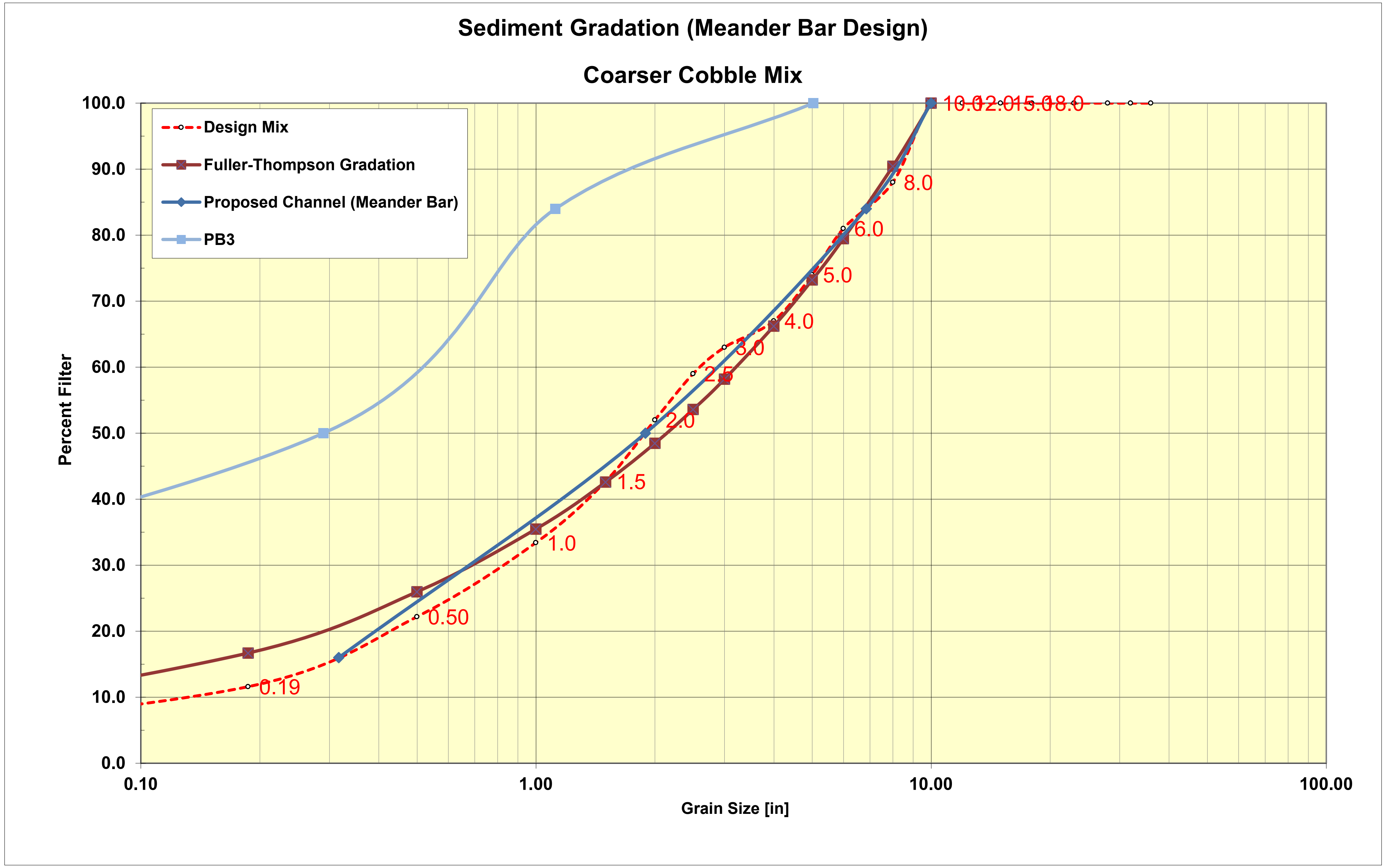
Slopes less than 5%

Sand/gravel streams with high relative submergence

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.05	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

Flow	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
Average Modeled Shear Stress (lb/ft^2)	0.53	0.76	0.86	0.92	0.97	1.06
τ_{ci}						
1.96	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.89	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.82	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.71	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.59	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.51	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.41	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.33	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.25	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.14	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.08	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
1.01	No Motion	No Motion	No Motion	No Motion	No Motion	Motion
0.93	No Motion	No Motion	No Motion	No Motion	Motion	Motion
0.88	No Motion	No Motion	No Motion	Motion	Motion	Motion
0.82	No Motion	No Motion	Motion	Motion	Motion	Motion
0.75	No Motion	Motion	Motion	Motion	Motion	Motion
0.67	No Motion	Motion	Motion	Motion	Motion	Motion
0.54	No Motion	Motion	Motion	Motion	Motion	Motion

D50	1.89	in
	0.16	ft
	48.1	mm

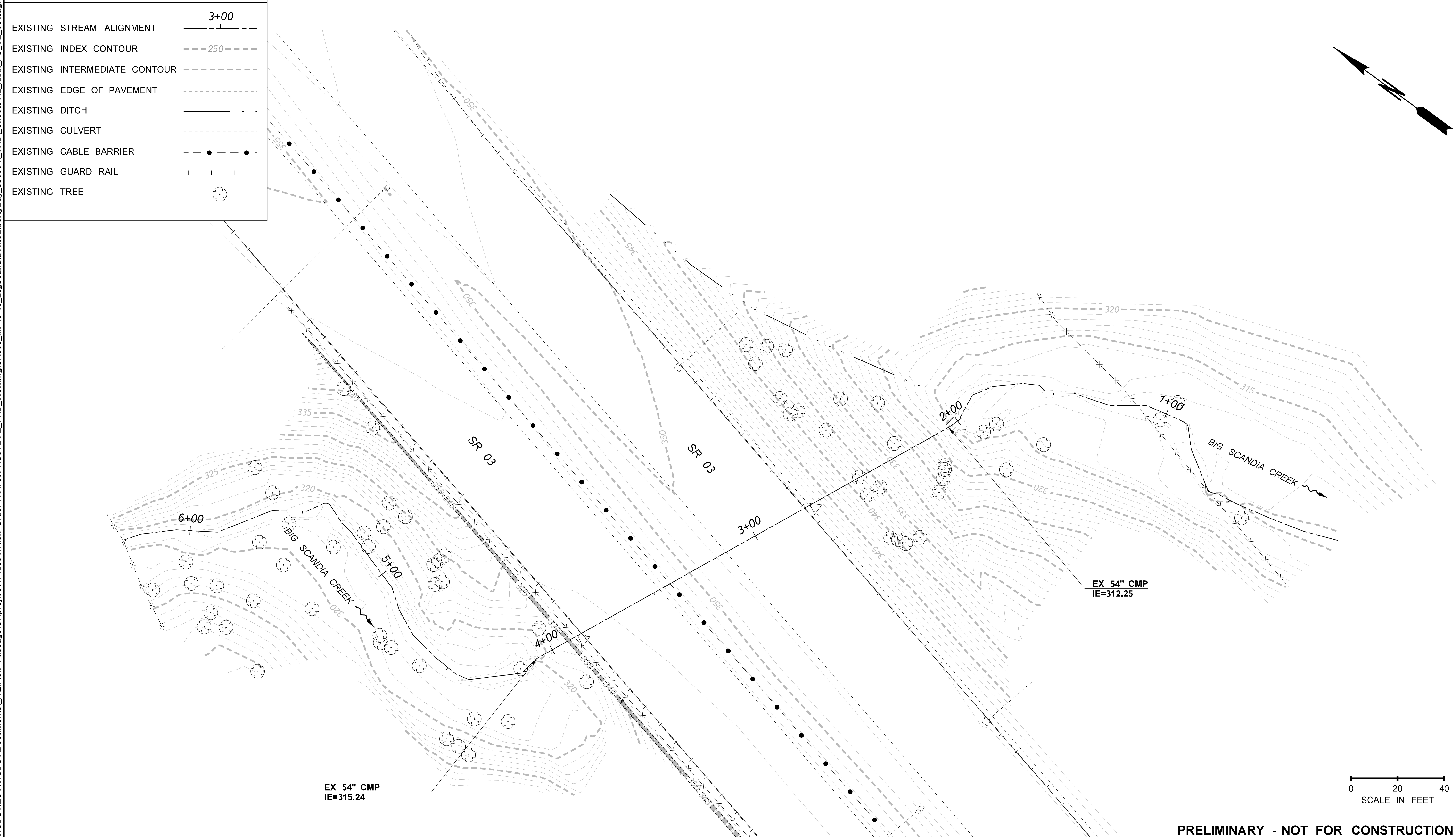


Fuller-Thompson Gradation	
Dmax =	10
D[in]	
12.000	108.55
10.000	100.00
8.000	90.45
6.000	79.46
5.000	73.20
4.000	66.21
3.000	58.17
2.500	53.59
2.000	48.47
1.500	42.58
1.000	35.48
0.500	25.97
0.187	16.69
0.017	5.63
0.003	2.58

Appendix D: Stream Plan Sheets, Profile, Details

LEGEND

EXISTING STREAM ALIGNMENT	3+00
EXISTING INDEX CONTOUR	250
EXISTING INTERMEDIATE CONTOUR	
EXISTING EDGE OF PAVEMENT	
EXISTING DITCH	
EXISTING CULVERT	
EXISTING CABLE BARRIER	
EXISTING GUARD RAIL	
EXISTING TREE	



PRELIMINARY - NOT FOR CONSTRUCTION

FILE NAME	c:\pw_wsdot\d0462777\XL_xxxx_PS_CE_001.dgn
TIME	12:54:19 PM
DATE	4/11/2022
PLOTTED BY	Mike Keilbart
DESIGNED BY	S. DHUNGEL
ENTERED BY	M. KEILBART
CHECKED BY	K. COMINGS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO. | LOCATION NO. XL_____

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

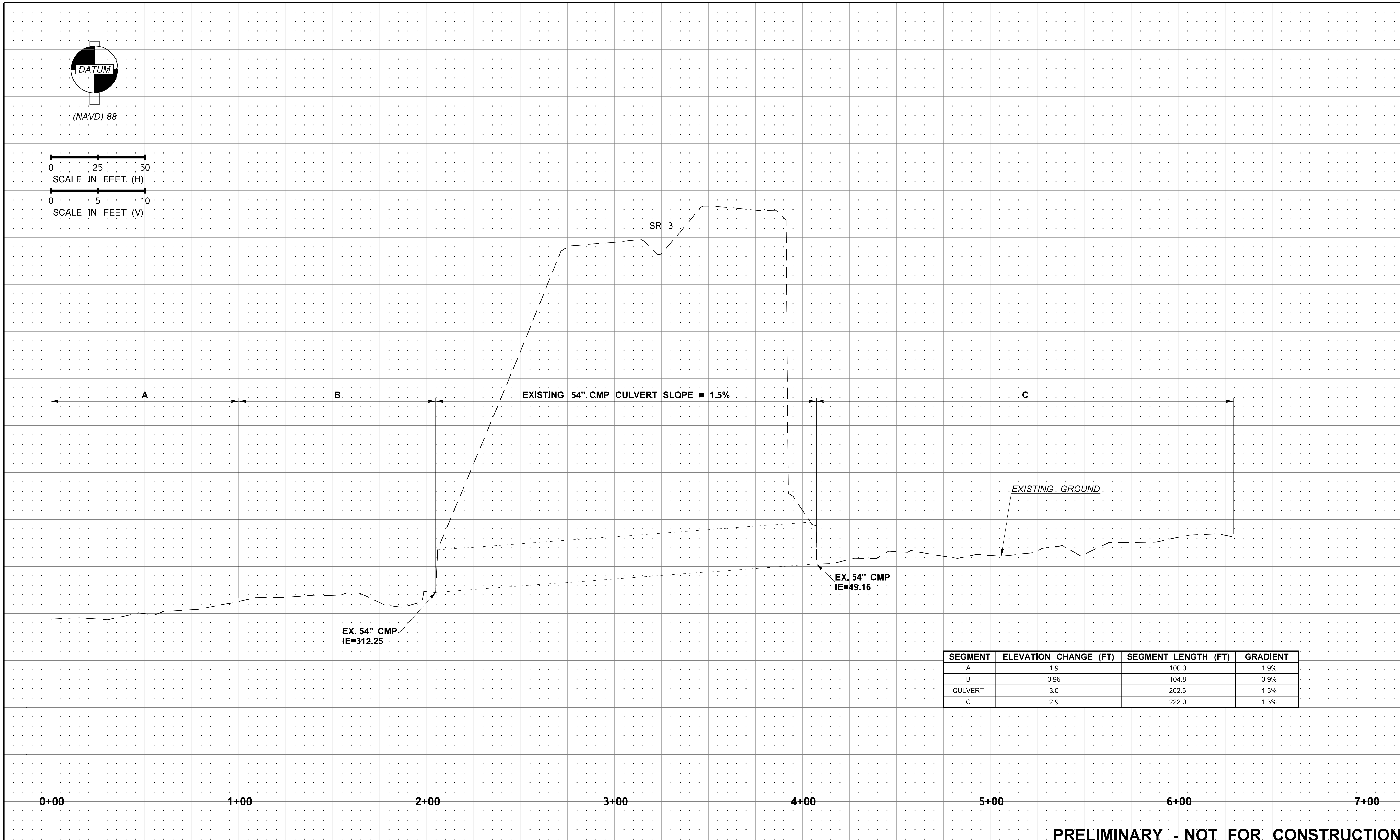
SR 3 MP 49.48
BIG SCANDIA CRK TO LIBERTY BAY
FISH BARRIER REMOVAL

EXISTING STREAM PLAN

PLAN REF NO CE1

SHEET 1 OF 5 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP49-48_BigScandiaCktoLibertyBay_996804_CAD_Sheets\XL_xxxx_PS_CE_001.dgn



SEGMENT	ELEVATION CHANGE (FT)	SEGMENT LENGTH (FT)	GRADIENT
A	1.9	100.0	1.9%
B	0.96	104.8	0.9%
CULVERT	3.0	202.5	1.5%
C	2.9	222.0	1.3%

PRELIMINARY - NOT FOR CONSTRUCTION

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP49-48_BigScandiaCktoLibertyBay_996804_CAD_Sheets\XL_xxxx_PS_PR_CE_001.dgn

FILE NAME	c:\pw_wsdot\d0462777\XL_xxxx_PS_PR_CE_001.dgn				
TIME	12:56:37 PM				
DATE	4/11/2022				
PLOTTED BY	Mike Keilbart				
DESIGNED BY	S. DHUNGEL				
ENTERED BY	M. KEILBART				
CHECKED BY	K. COMINGS				
PROJ. ENGR.	J. HEILMAN				
REGIONAL ADM.		REVISION	DATE	BY	

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL_____

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State
Department of Transportation

SR 3 MP 49.48
BIG SCANDIA CRK TO LIBERTY BAY
FISH BARRIER REMOVAL

EXISTING STREAM PROFILE

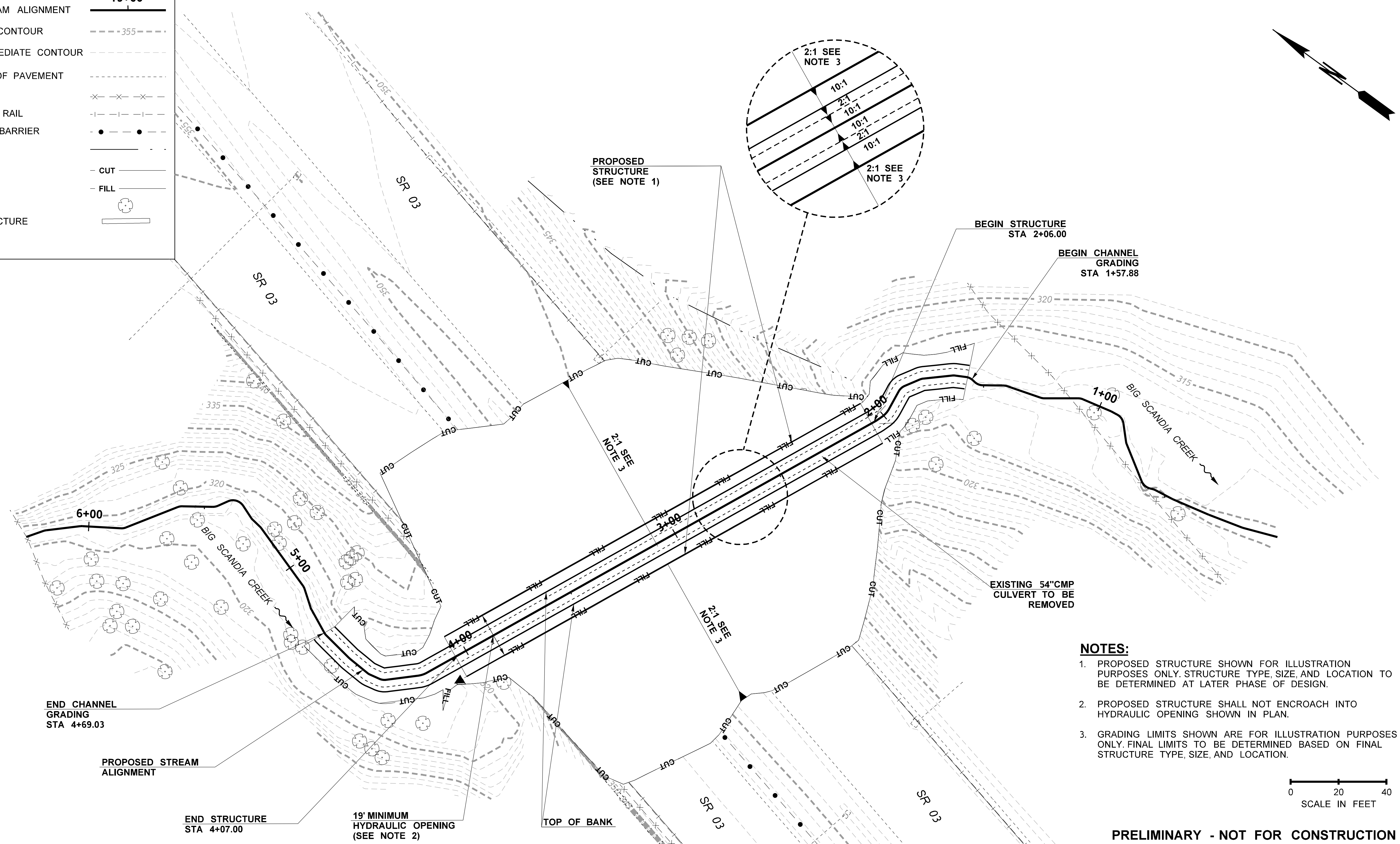
PLAN REF. NO. CP1

SHEET 2 OF 5 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP49-48_BigScandiaCktoLibertyBay_996804_CAD_Sheets\XL_xxxx_PS_CR_001.dgn

LEGEND

PROPOSED STREAM ALIGNMENT	15+00
EXISTING INDEX CONTOUR	355
EXISTING INTERMEDIATE CONTOUR	
EXISTING EDGE OF PAVEMENT	
EXISTING FENCE	
EXISTING GUARD RAIL	
EXISTING CABLE BARRIER	
EXISTING DITCH	
CUT LINE	CUT
FILL LINE	FILL
EXISTING TREE	
PROPOSED STRUCTURE	



NOTES:

1. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATION PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED AT LATER PHASE OF DESIGN.
2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN IN PLAN.
3. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE, AND LOCATION.

0 20 40
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

FILE NAME	c:\pw_wsdot\d0462777\XL_xxxx_PS_CR_001.dgn
TIME	1:02:08 PM
DATE	4/11/2022
PLOTTED BY	Mike Keilbart
DESIGNED BY	S DHUNGEL
ENTERED BY	M. KEILBART
CHECKED BY	K. COMINGS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO. | LOCATION NO. XL_____

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

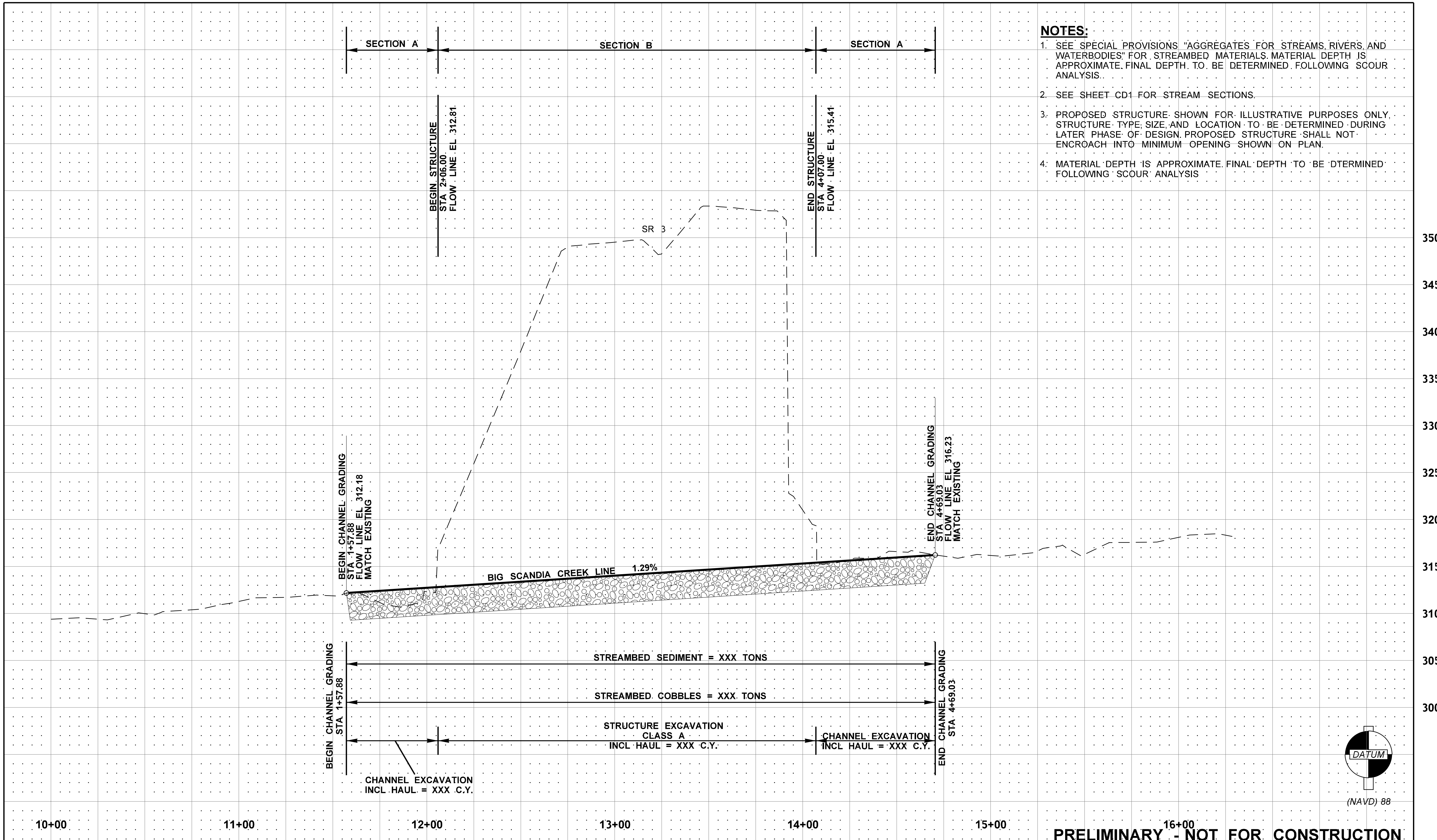
Washington State Department of Transportation

SR 3 MP 49.48
BIG SCANDIA CRK TO LIBERTY BAY
FISH BARRIER REMOVAL

PROPOSED STREAM PLAN

PLAN REF NO CR1

SHEET 3 OF 5 SHEETS



NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIALS. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.
2. SEE SHEET CD1 FOR STREAM SECTIONS.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY, STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.
4. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DTERMINED FOLLOWING SCOUR ANALYSIS

PRELIMINARY - NOT FOR CONSTRUCTION

pw:\\HOOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP49-48_BigScandiaCktoLibertyBay_996804_CAD_Sheets\XL_xxxx_PS_PR_CP_001.dgn

FILE NAME	c:\pw_wsdot\d0462777\XL_xxxx_PS_PR_CP_001.dgn			
TIME	1:17:20 PM			
DATE	4/11/2022			
PLOTTED BY	Mike Keilbart			
DESIGNED BY	S. DHUNGEL			
ENTERED BY	M. KEILBART			
CHECKED BY	K. COMINGS			
PROJ. ENGR.	J. HEILMAN			
REGIONAL ADM.		REVISION	DATE	BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO. | LOCATION NO. XL_____

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

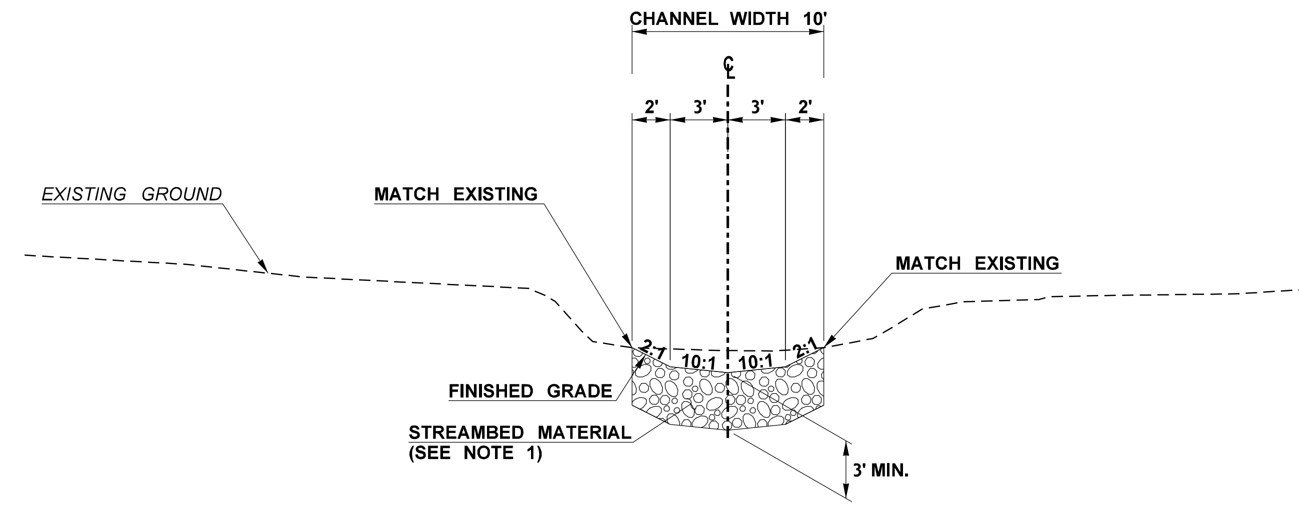
Washington State Department of Transportation

SR 3 MP 49.48
BIG SCANDIA CRK TO LIBERTY BAY
FISH BARRIER REMOVAL

STREAM PROFILE

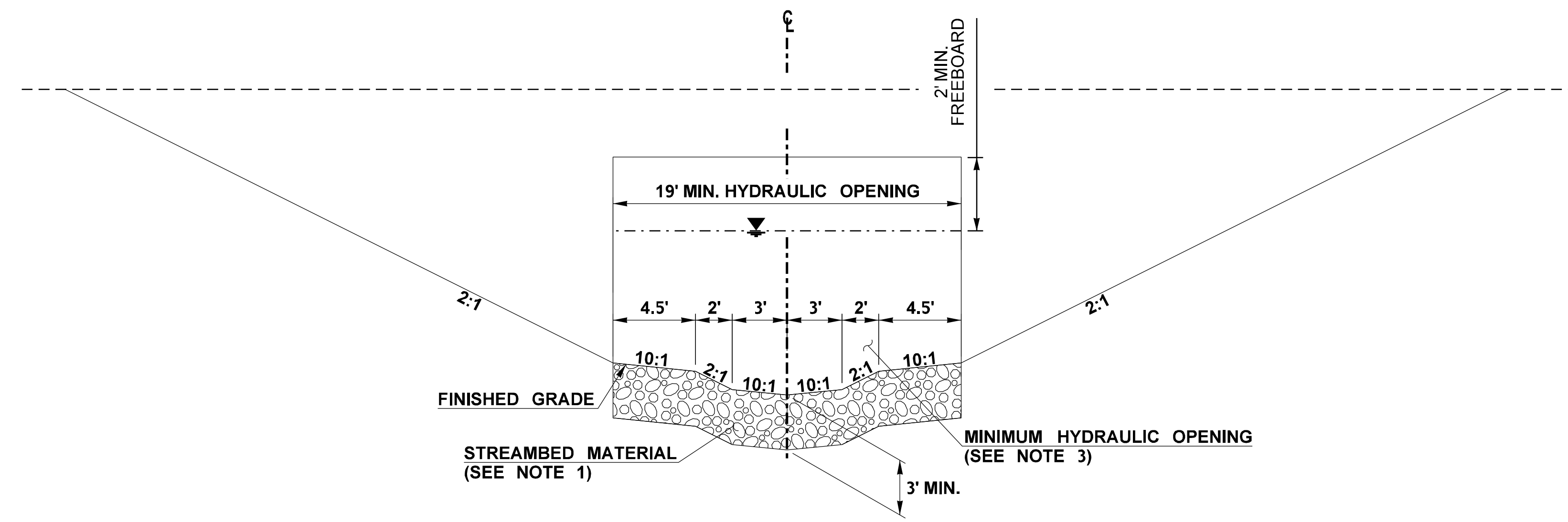
PLAN REF. NO. CP2

SHEET 4 OF 5 SHEETS



SECTION A

BIG SCANDIA CREEK
STA 1+57.88 TO 2+06.00
STA 4+07.00 TO 4+69.03



SECTION B

BIG SCANDIA CREEK
STA 2+06.00 TO 4+07.00

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATE FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.
2. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE, AND STRUCTURE LOCATION.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING ON PLAN.

PRELIMINARY - NOT FOR CONSTRUCTION

FILE NAME	c:\pw_wsdot\d0462777\XL_xxxx_DE_CD_001.dgn
TIME	1:18:12 PM
DATE	4/11/2022
PLOTTED BY	Mike Keilbart
DESIGNED BY	S. DHUNGEL
ENTERED BY	M. KEILBART
CHECKED BY	K. COMINGS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL_____

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MP 49.48
BIG SCANDIA CRK TO LIBERTY BAY
FISH BARRIER REMOVAL

STREAM DETAILS

PLAN REF NO CD1

SHEET 5 OF 5 SHEETS

Appendix E: Manning's Calculations

(Not used)

Appendix F: Large Woody Material Calculations

WSDOT Large Woody Material for stream restoration metrics calculator

State Route# & MP	*SR3*	Key piece volume	*1.310*	*yd3*
Stream name	*Big Scandia Creek*	Key piece/ft	*0.0335*	*per ft stream*
length of regrade[a]	*313* ft	Total wood vol./ft	*0.3948*	*yd3/ft stream*
Bankfull width	*10* ft	Total LWM[c] pieces/ft stream	*0.1159*	*per ft stream*
Habitat zone[b]	*Western WA*			

Log type	*Diameter at midpoint (ft)*	*Length(ft)[d]*	*Volume (yd^3/log)[d]*	*Rootwad?*	*Qualifies as key piece?*	*No. LWM pieces*	*Total wood volume (yd^3)*
A	2.00	*30*	3.49	yes	yes	6	20.94
B	1.50	*25*	1.64	yes	yes	6	9.82
C	1.00	*20*	0.58	yes	no	10	5.82
D	0.5	*10*	0.07	no	no	14	1.02
E			0.00				0.00
F			0.00				0.00
G			0.00				0.00
H			0.00				0.00
I			0.00				0.00
J			0.00				0.00
K			0.00				0.00
L			0.00				0.00
M			0.00				0.00
N			0.00				0.00
O			0.00				0.00
P			0.00				0.00

	No. of key pieces	Total No. of LWM pieces	Total LWM volume (yd^3)
Design	12	36	37.6
Targets	**10**	**36**	**123.6**
	surplus	on target	deficit

[a] includes length through crossing, regardless of structure type

[b] choose one of the following Forest Regions in the drop-down menu (if in doubt ask HQ Biology). See also the Forest Region tab for additional information

Western Washington lo\	(generally <4,200 ft. in elevation west of the Cascade Crest)
Alpine	(generally > 4,200 ft. in elevation and down to ~3,700 ft. in elevation east of the Cascade crest)
Douglas fir-Ponderosa p	(mainly east slope Cascades below 3,700 ft. elevation)

[c] LWM (Large Woody Material), also known as LWD (Large Woody Debris) is defined as a piece of wood at least 10 cm (4") diam. X 2 m (6ft) long (Fox 2001).

[d] includes rootwad if present

Appendix G: Future Projections for Climate-Adapted Culvert Design

Future Projections for Climate-Adapted Culvert Design

Project Name: GEC Bundle 1 PHD

Stream Name: Big Scandia Cr SR 3 MP 49.48

Drainage Area: 261 ac

Projected mean percent change in bankfull flow:

2040s: 14.4%

2080s: 17.4%

Projected mean percent change in bankfull width:

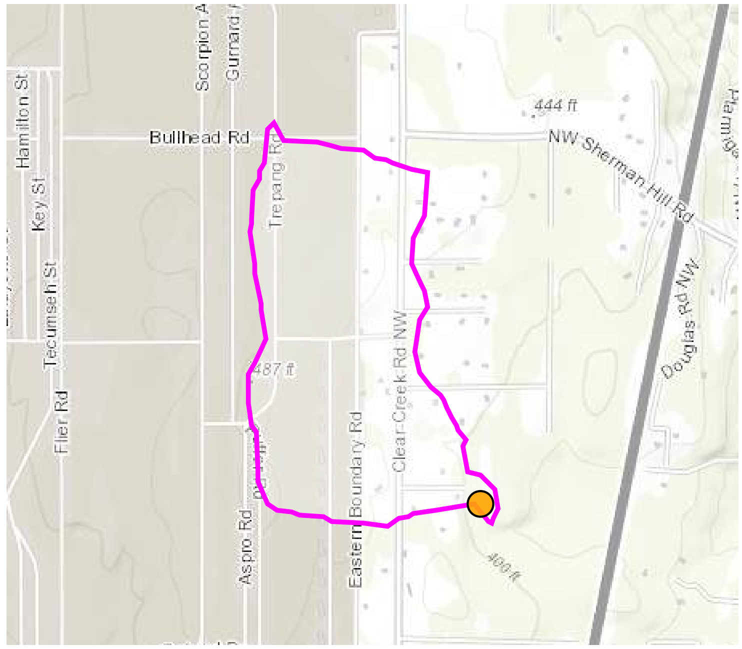
2040s: 6.9%

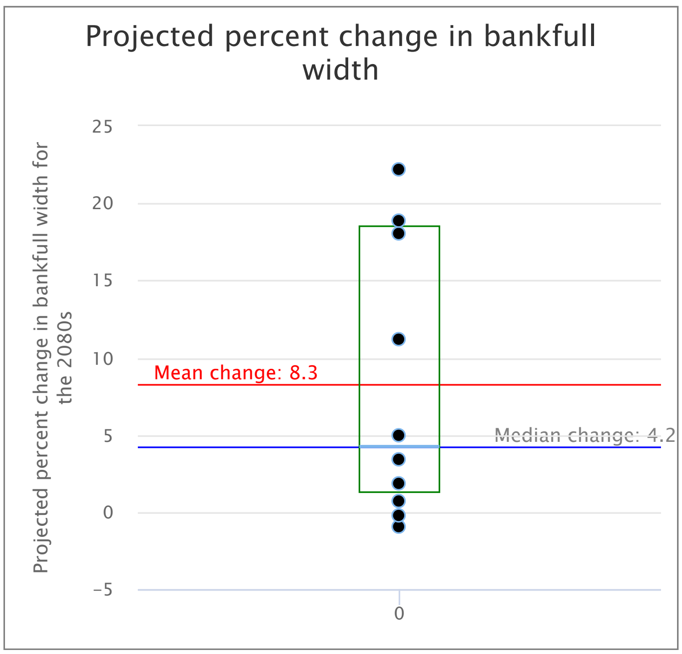
2080s: 8.3%

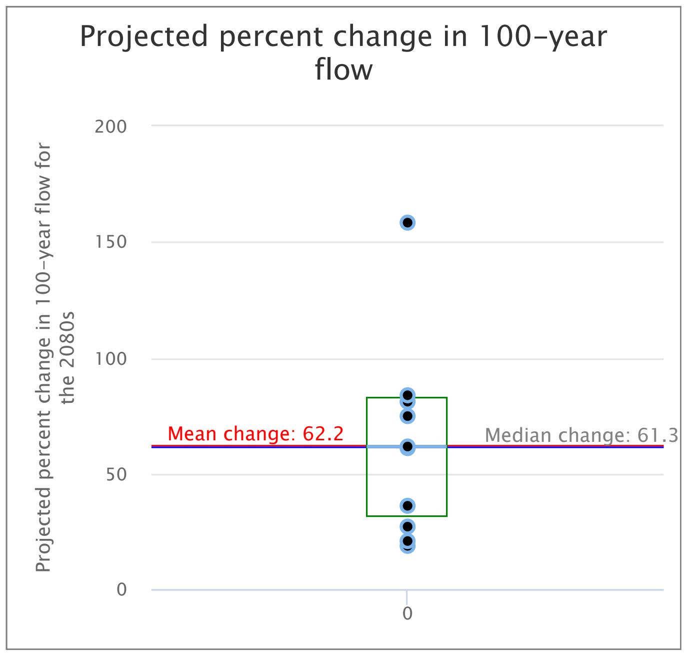
Projected mean percent change in 100-year flood:

2040s: 45.2%

2080s: 62.2%







Black dots are projections from 10 separate models

Appendix H: SRH-2D Model Results

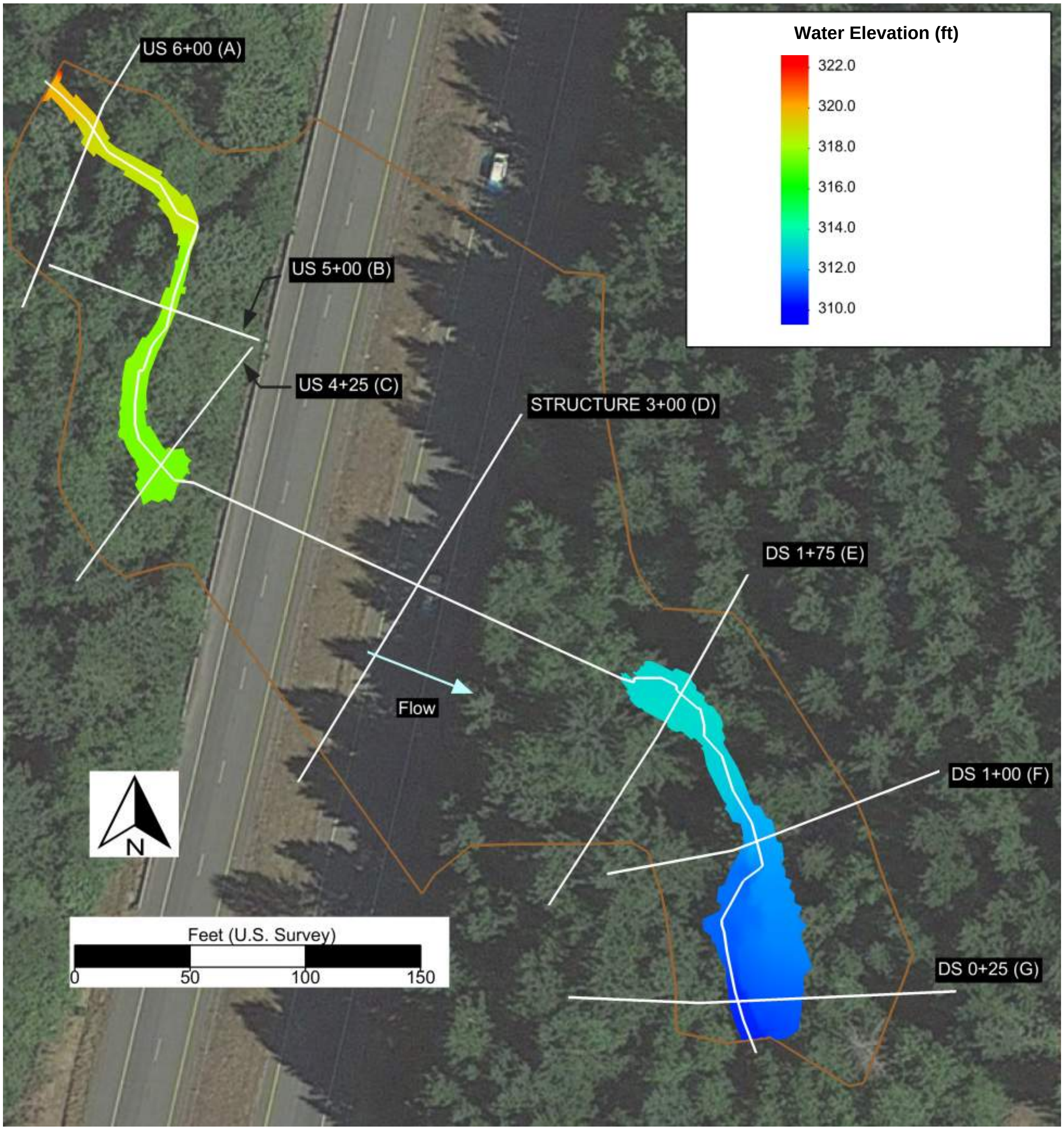


Fig H-1: Existing Conditions 2-yr water surface elevation

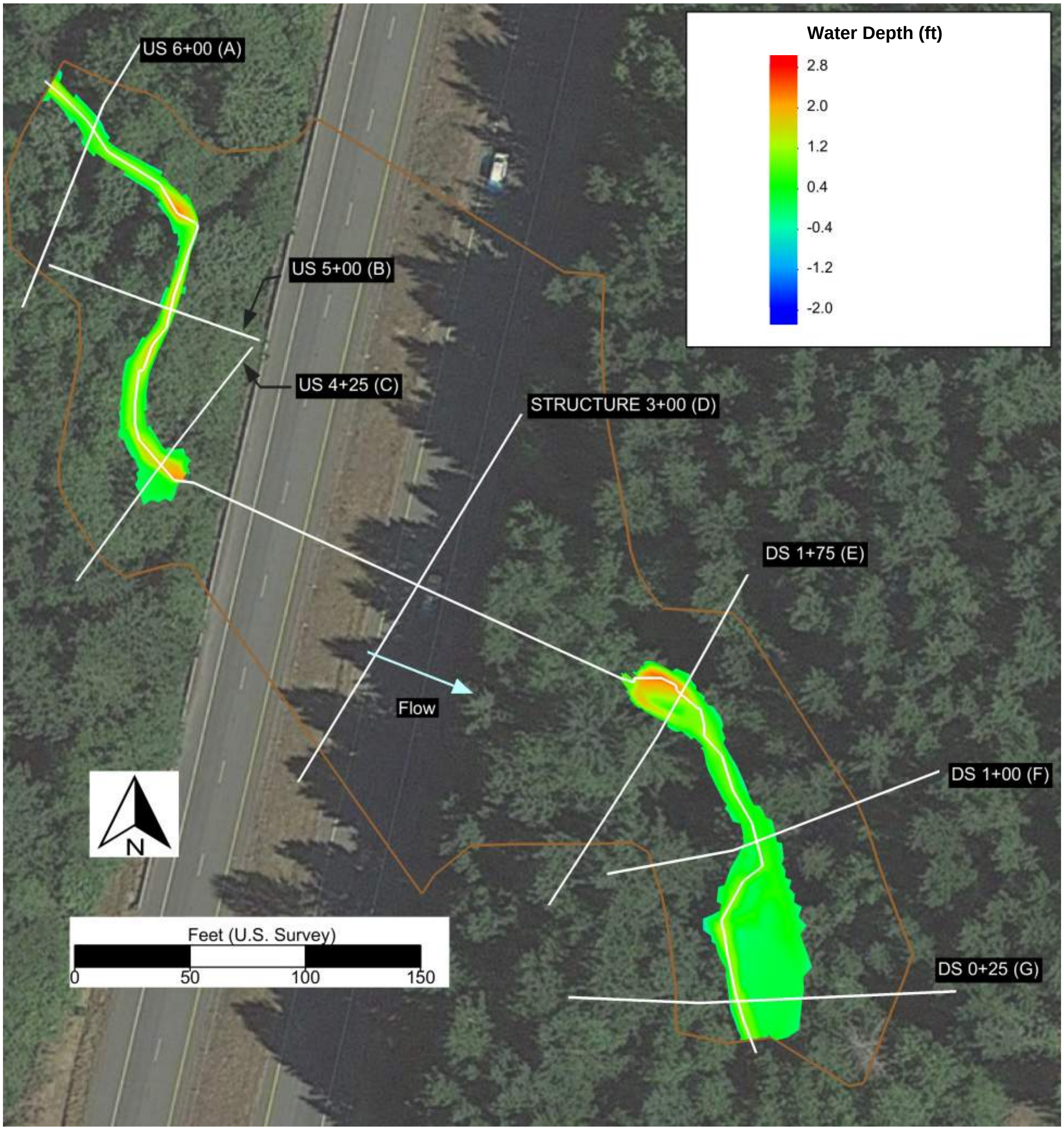


Fig H-2: Existing Conditions 2-yr water depth

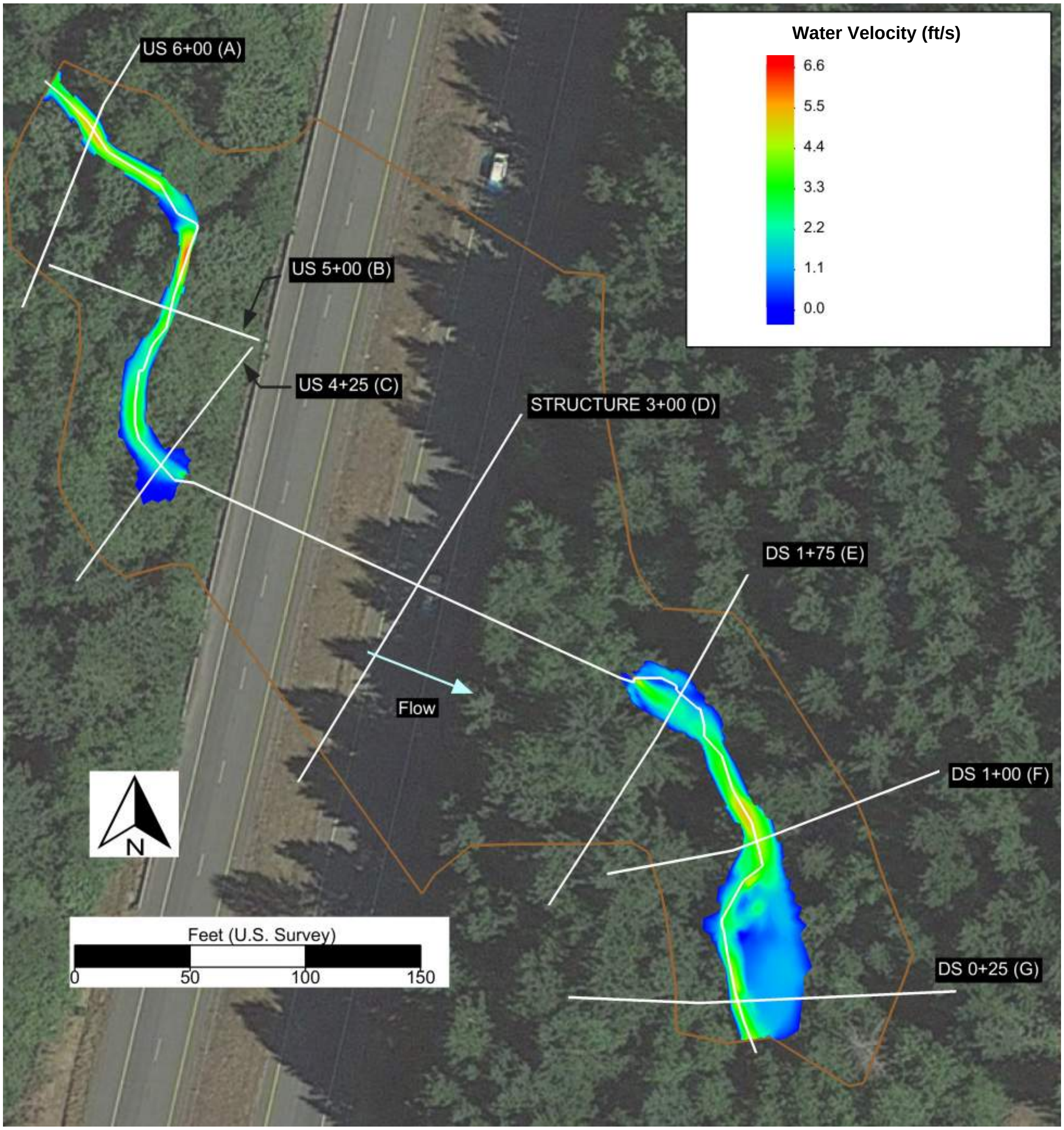


Fig H-3: Existing Conditions 2-yr water velocity

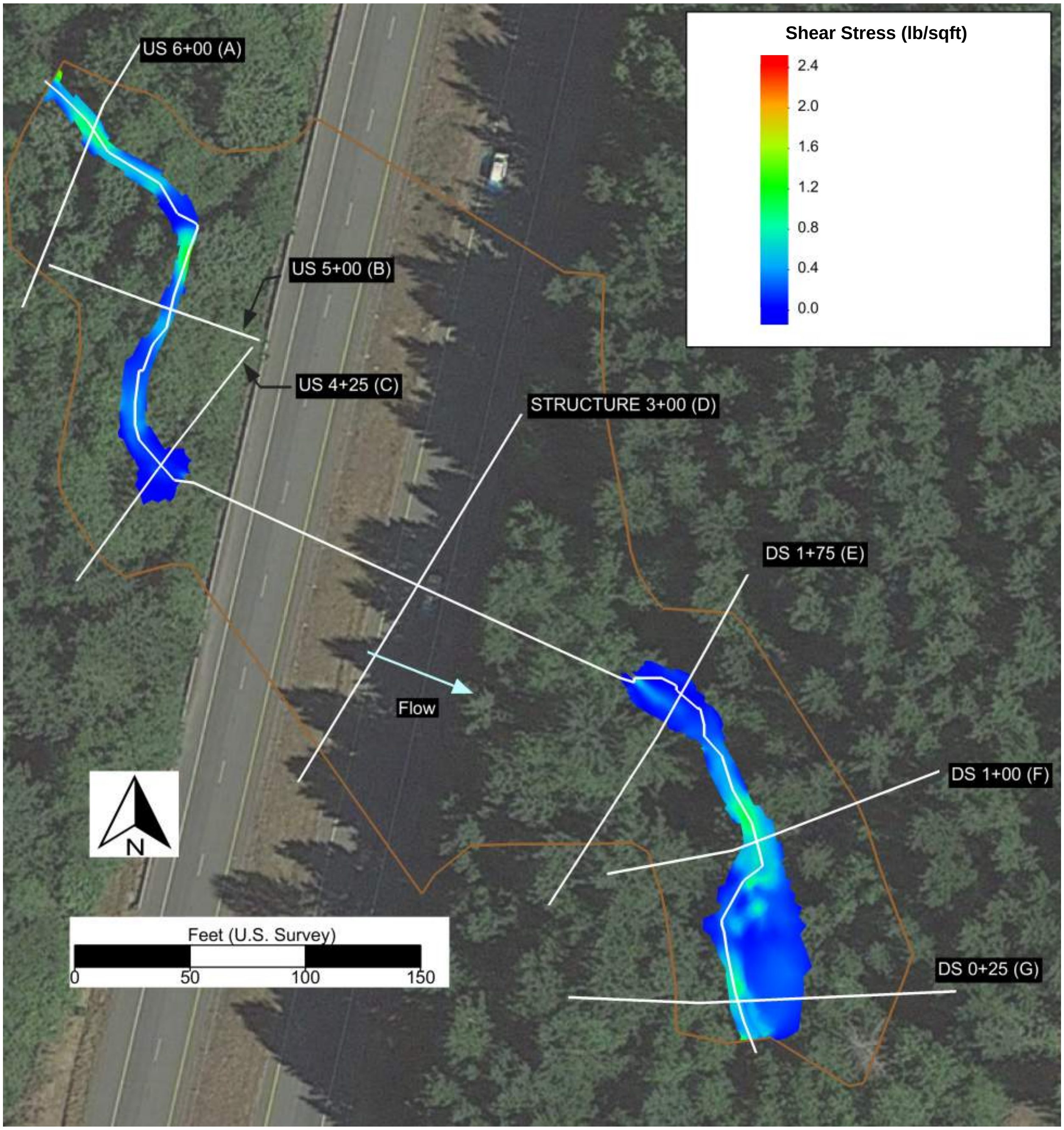


Fig H-4: Existing Conditions 2-yr shear stress

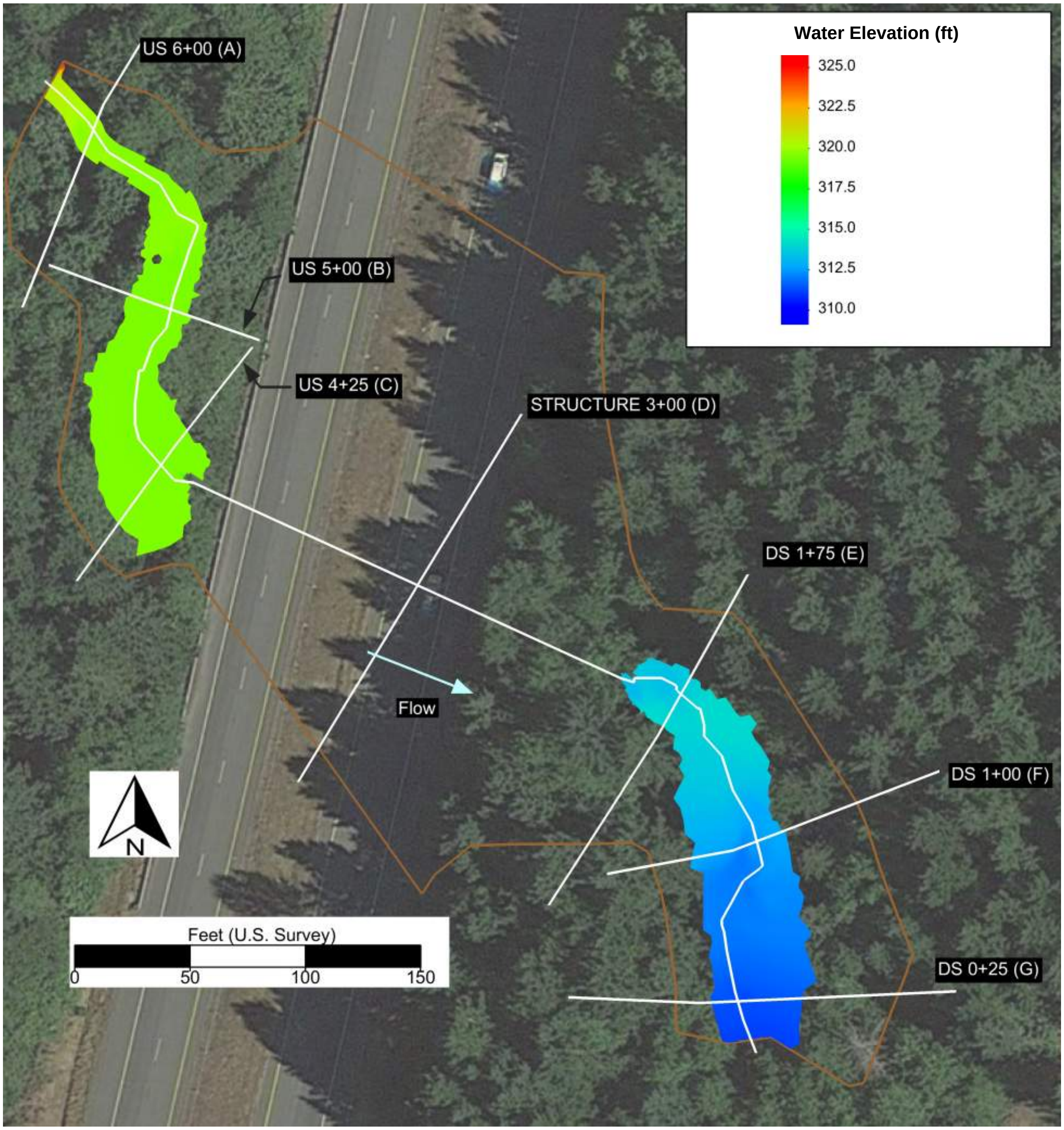


Fig H-5: Existing Conditions 100-yr water surface elevation

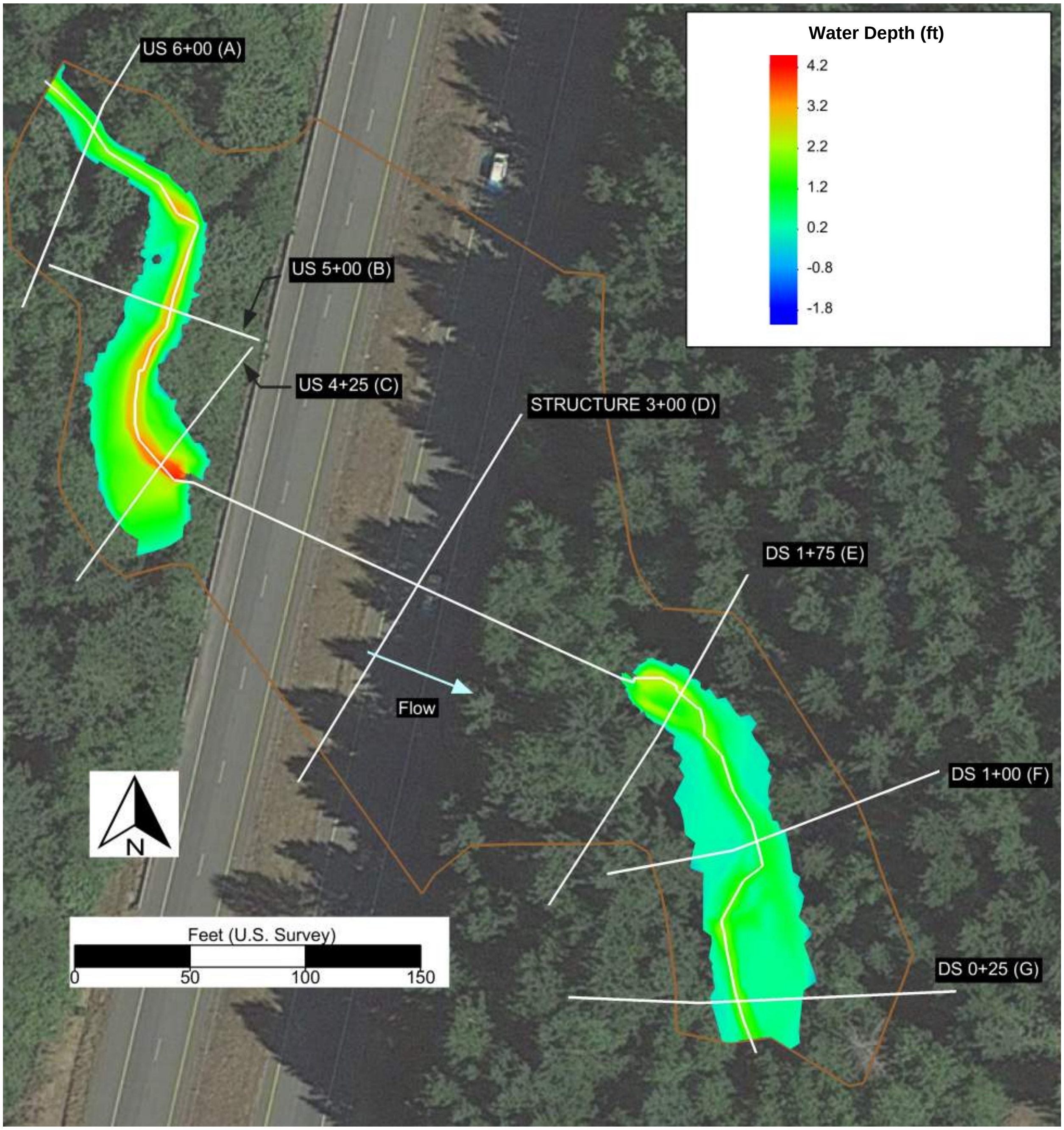


Fig H-6: Existing Conditions 100-yr water depth

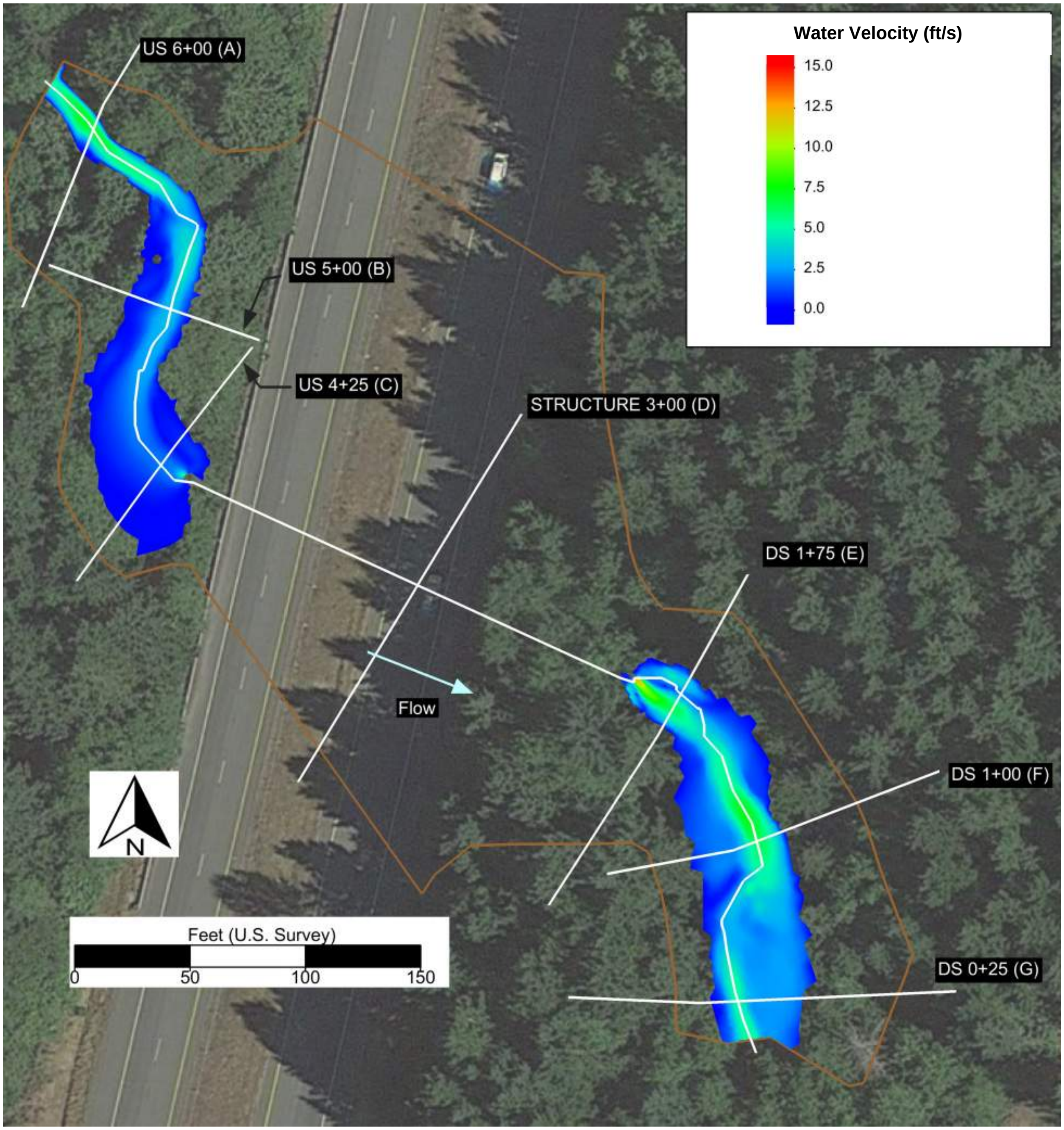


Fig H-7: Existing Conditions 100-yr water velocity

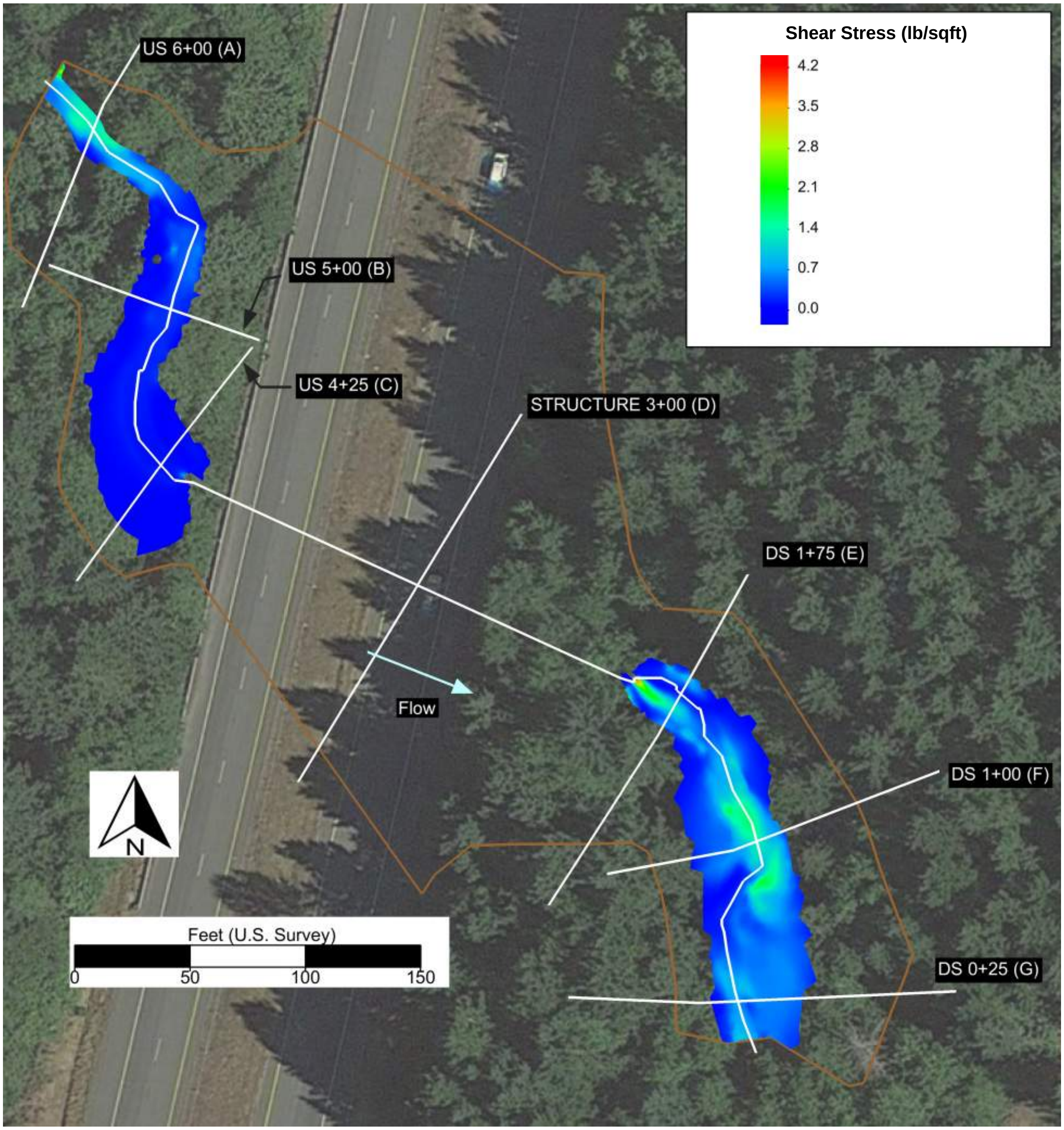


Fig H-8: Existing Conditions 100-yr shear stress

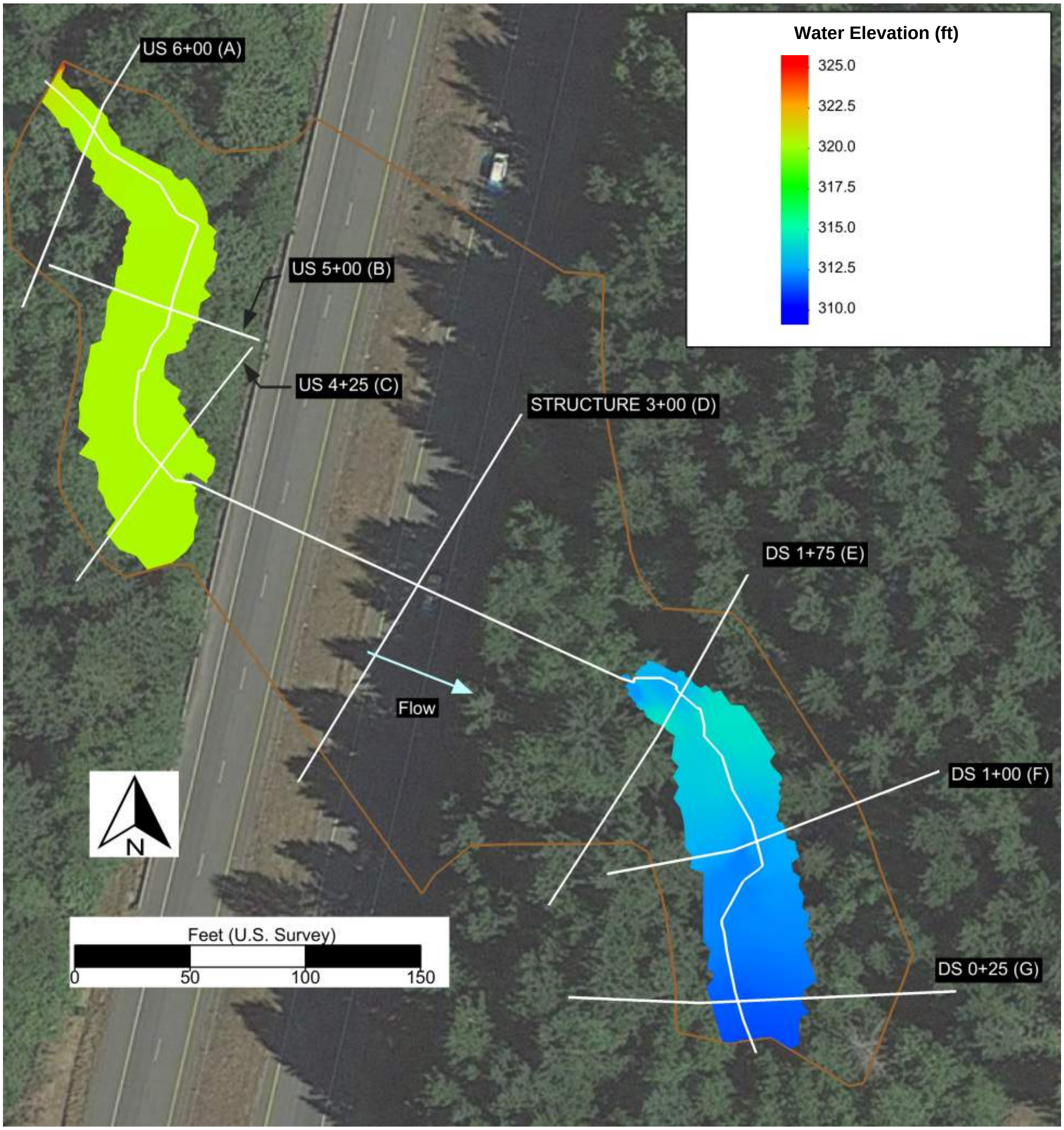


Fig H-9: Existing Conditions 500-yr water surface elevation

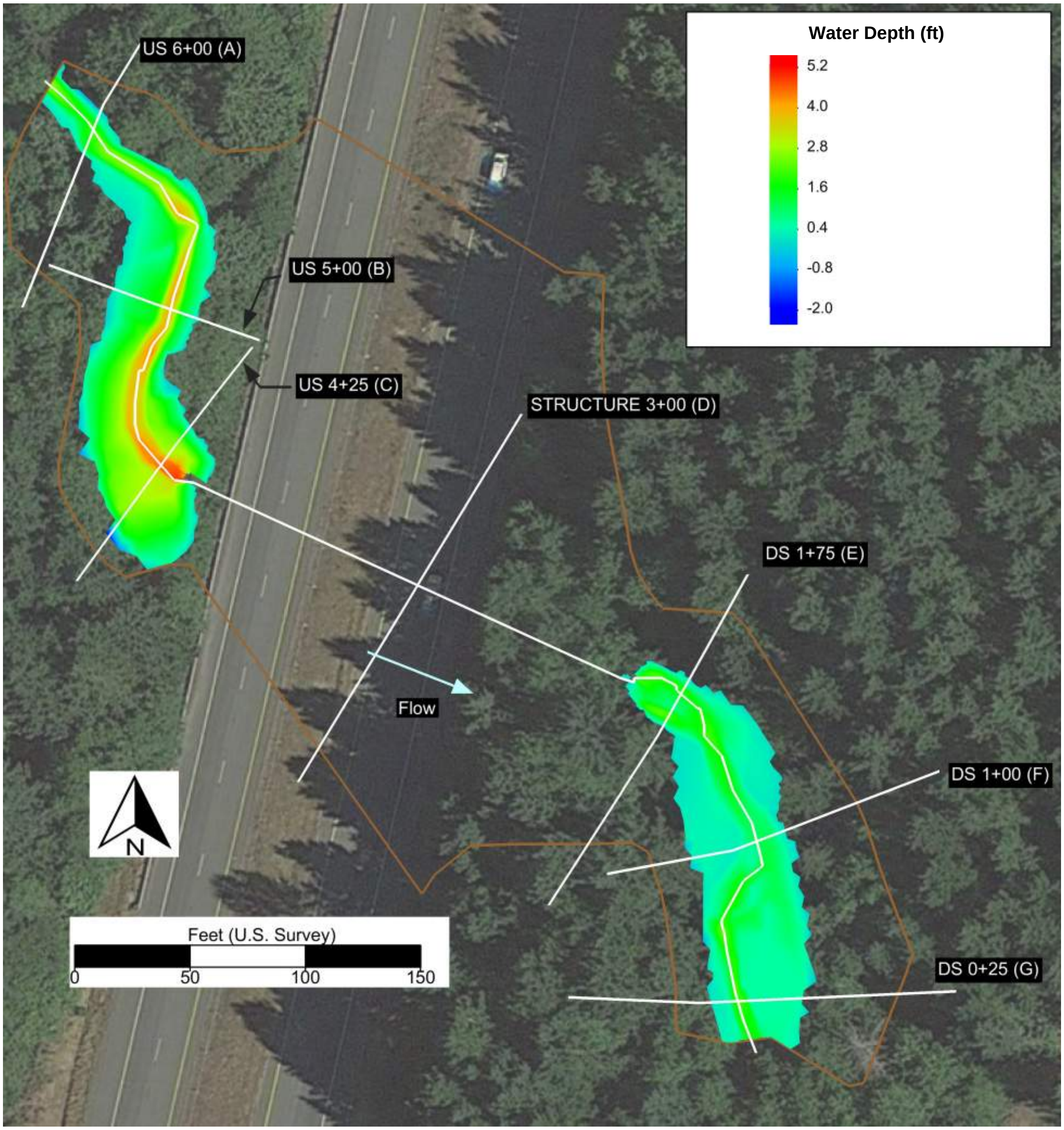


Fig H-10: Existing Conditions 500-yr water depth

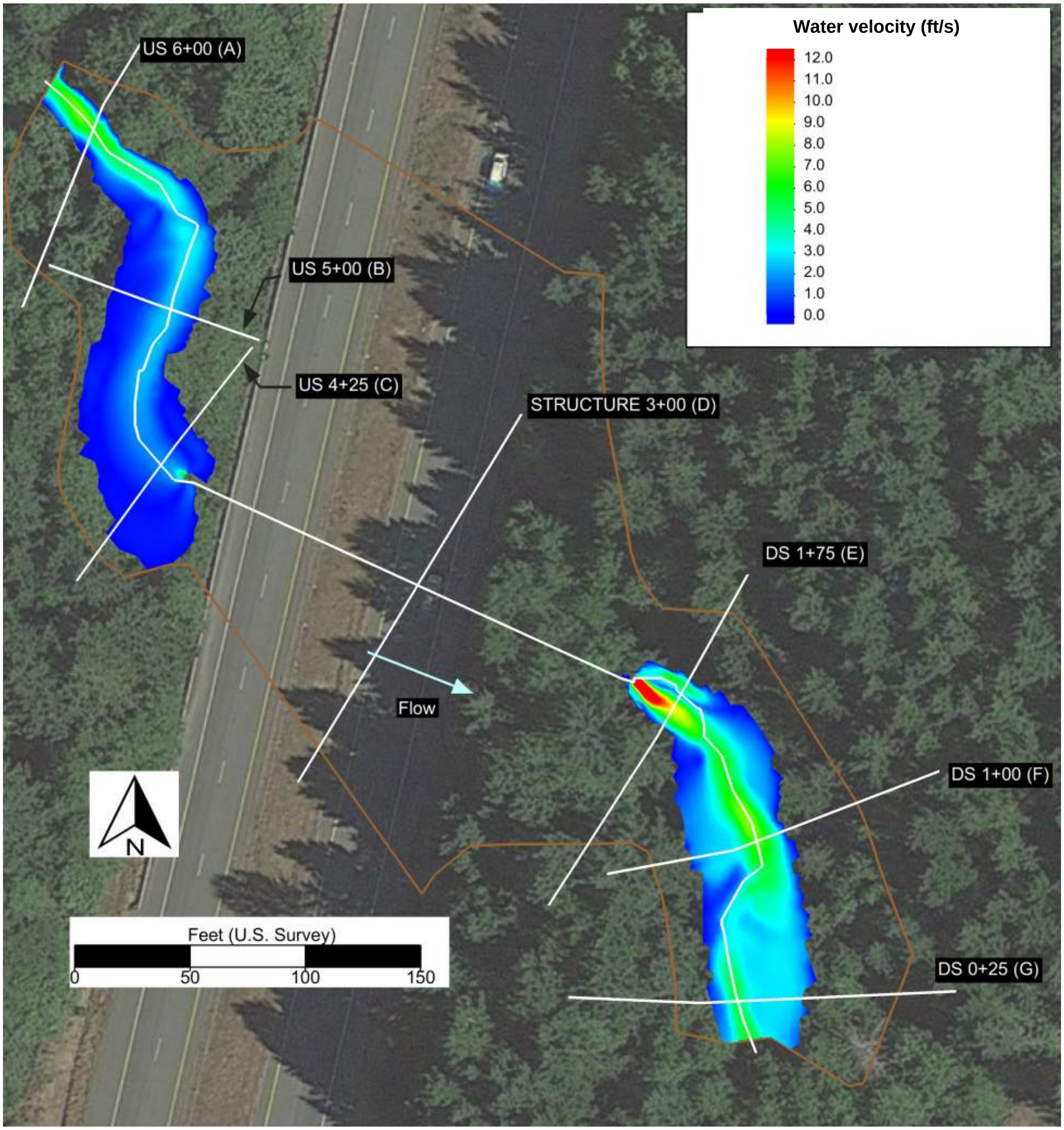


Fig H-11: Existing Conditions 500-yr water velocity

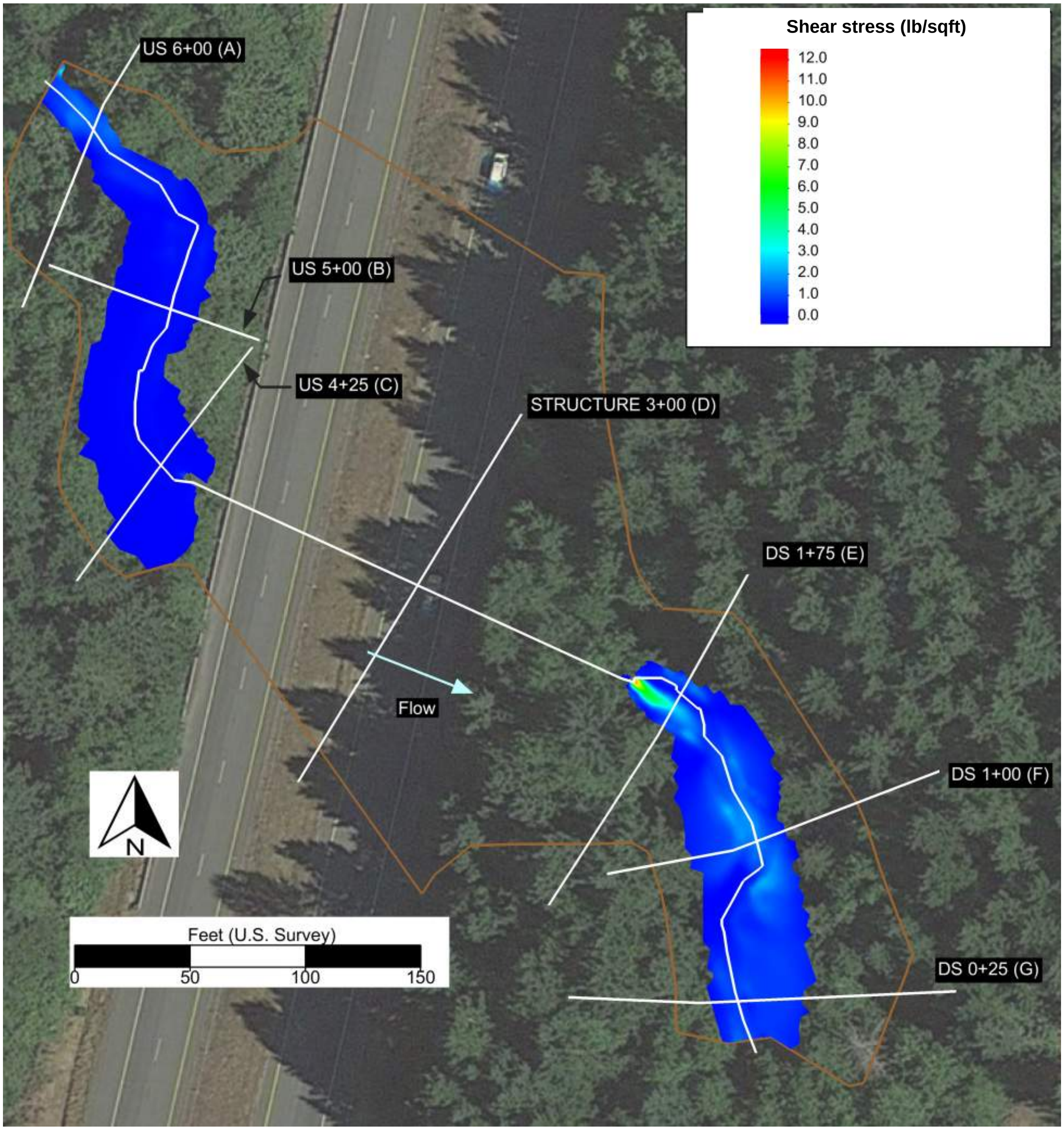


Fig H-12: Existing Conditions 500-yr shear stress

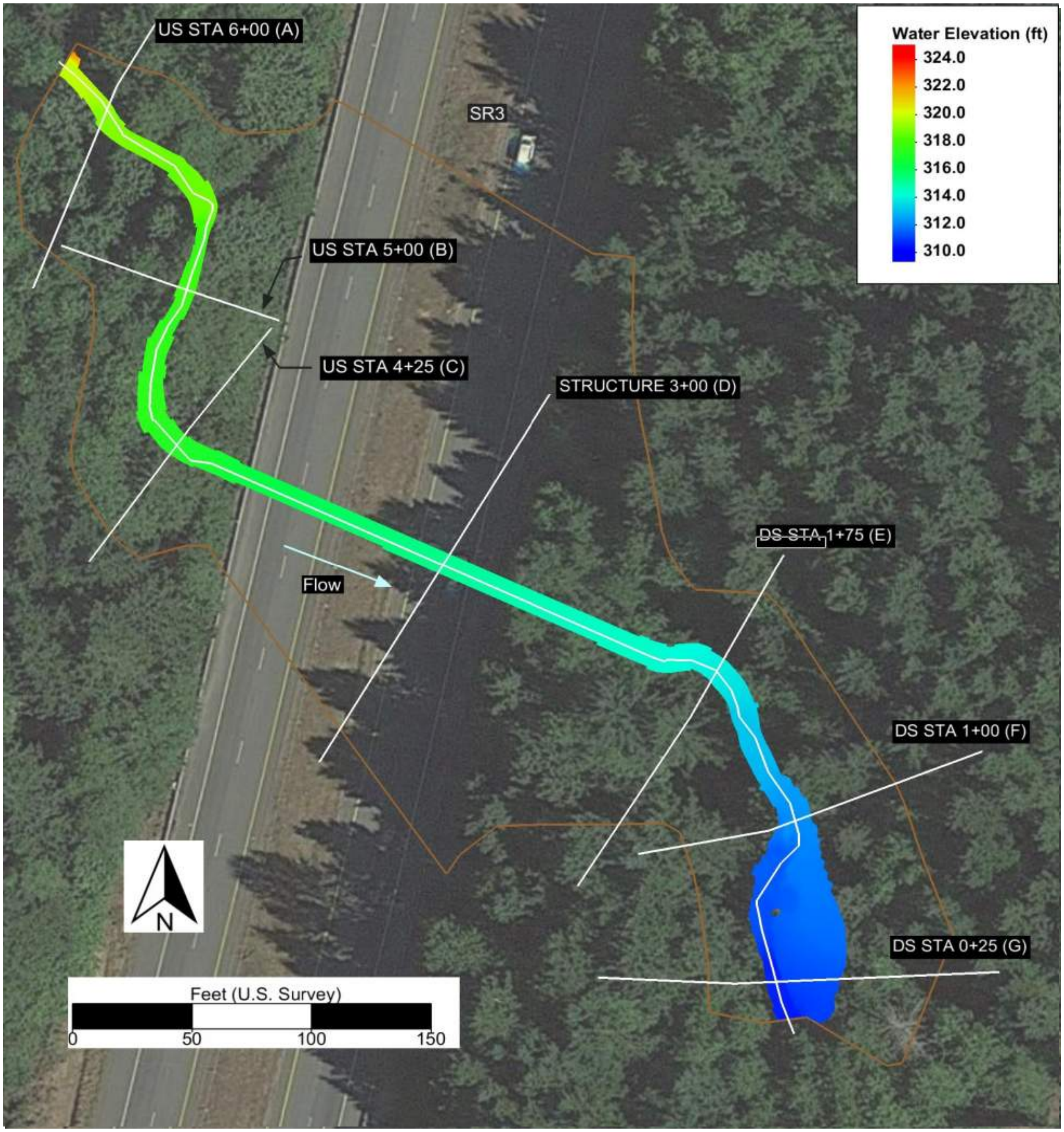


Fig H-13: Proposed Conditions 2-yr water surface elevation

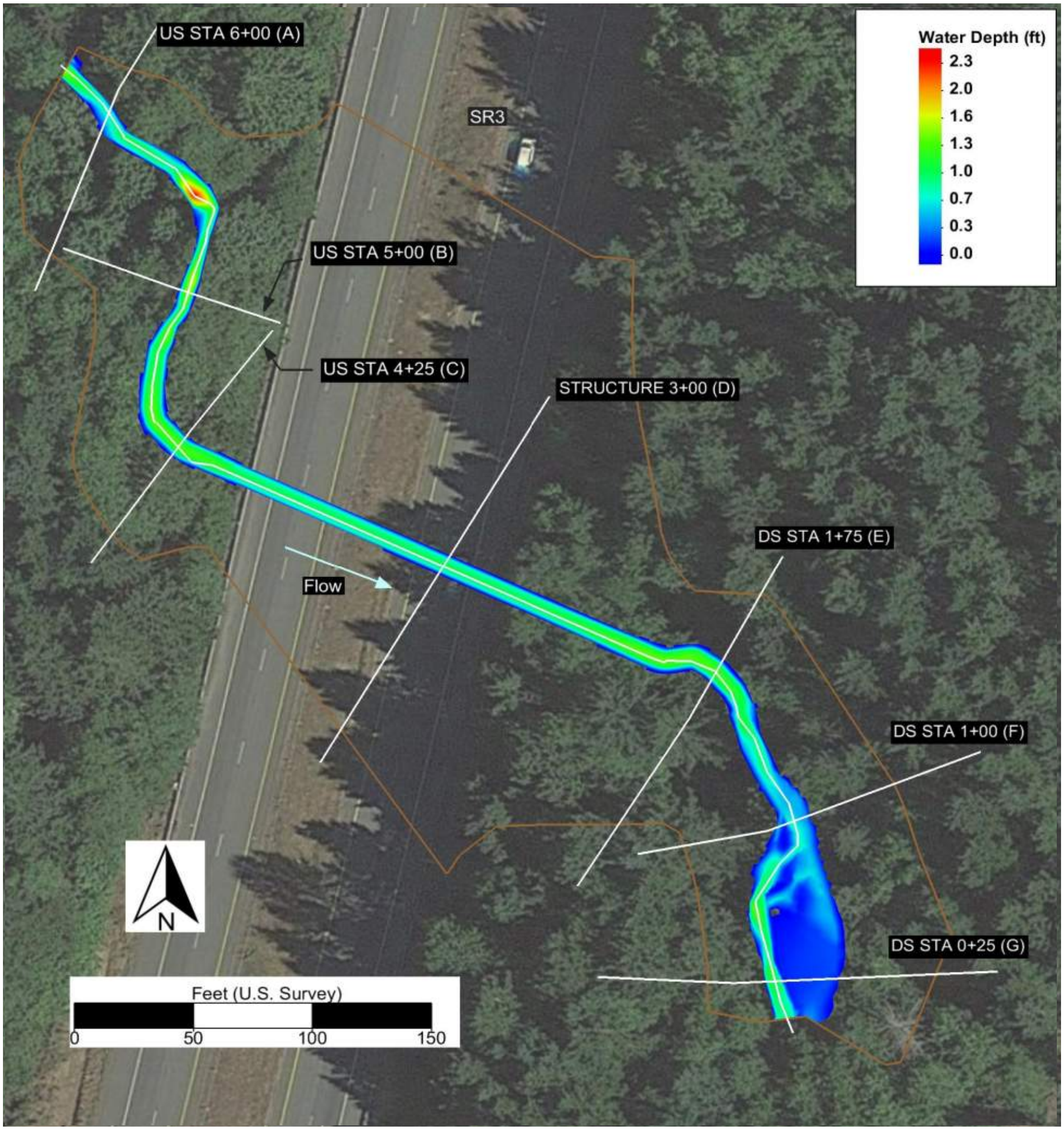


Fig H-14: Proposed Conditions 2-yr water depth

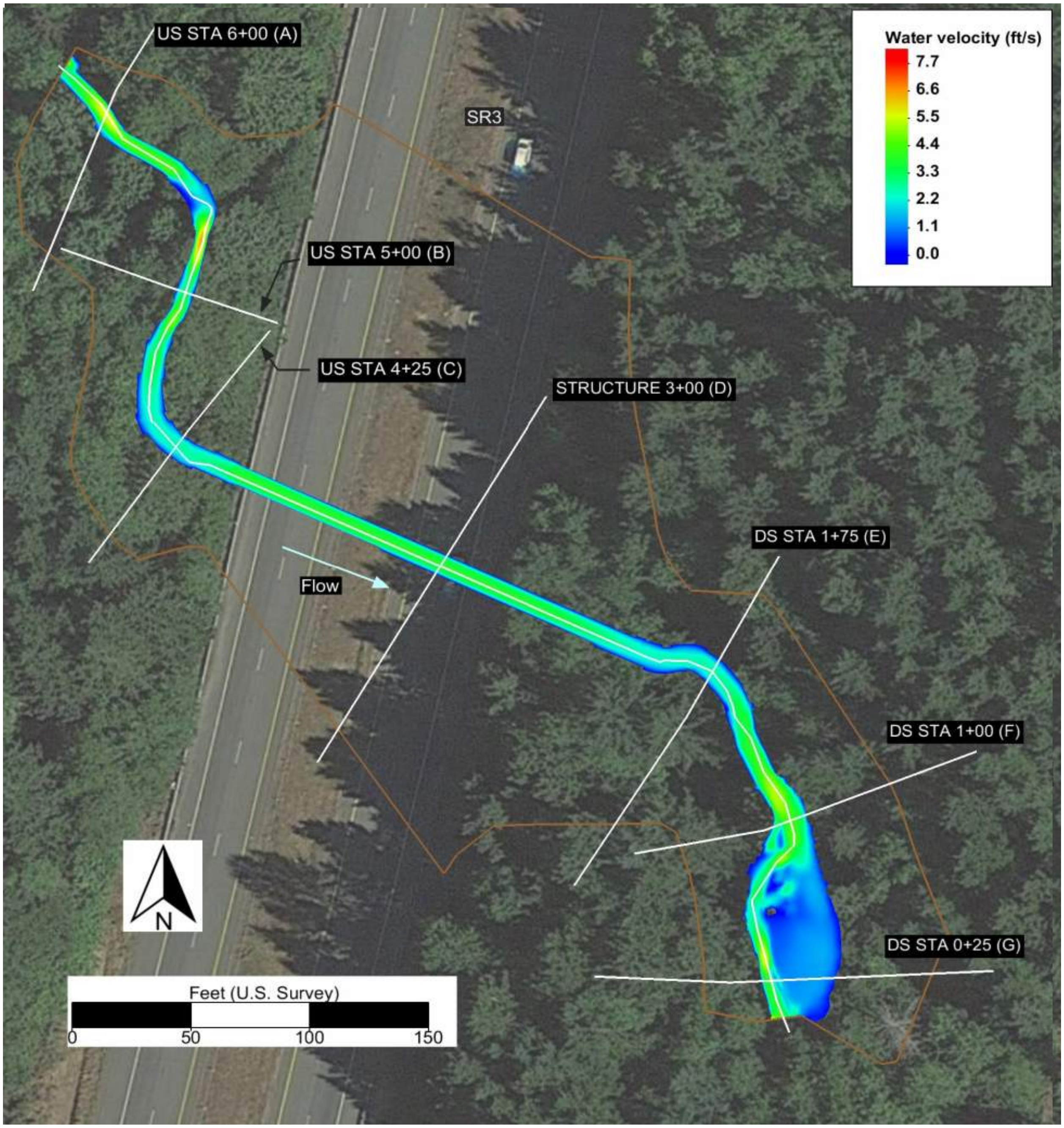


Fig H-15: Proposed Conditions 2-yr velocity

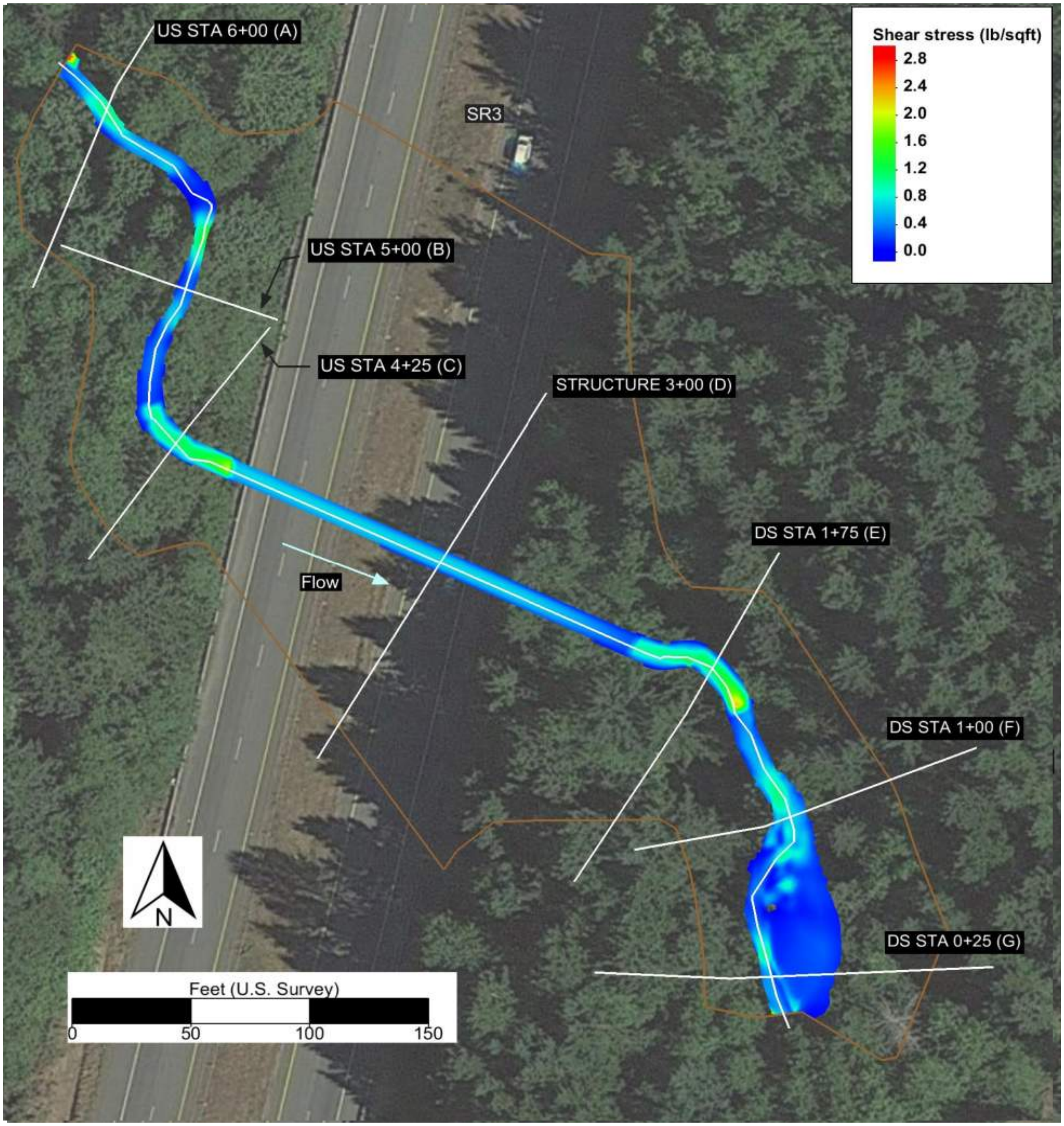


Fig H-16: Proposed Conditions 2-yr shear stress

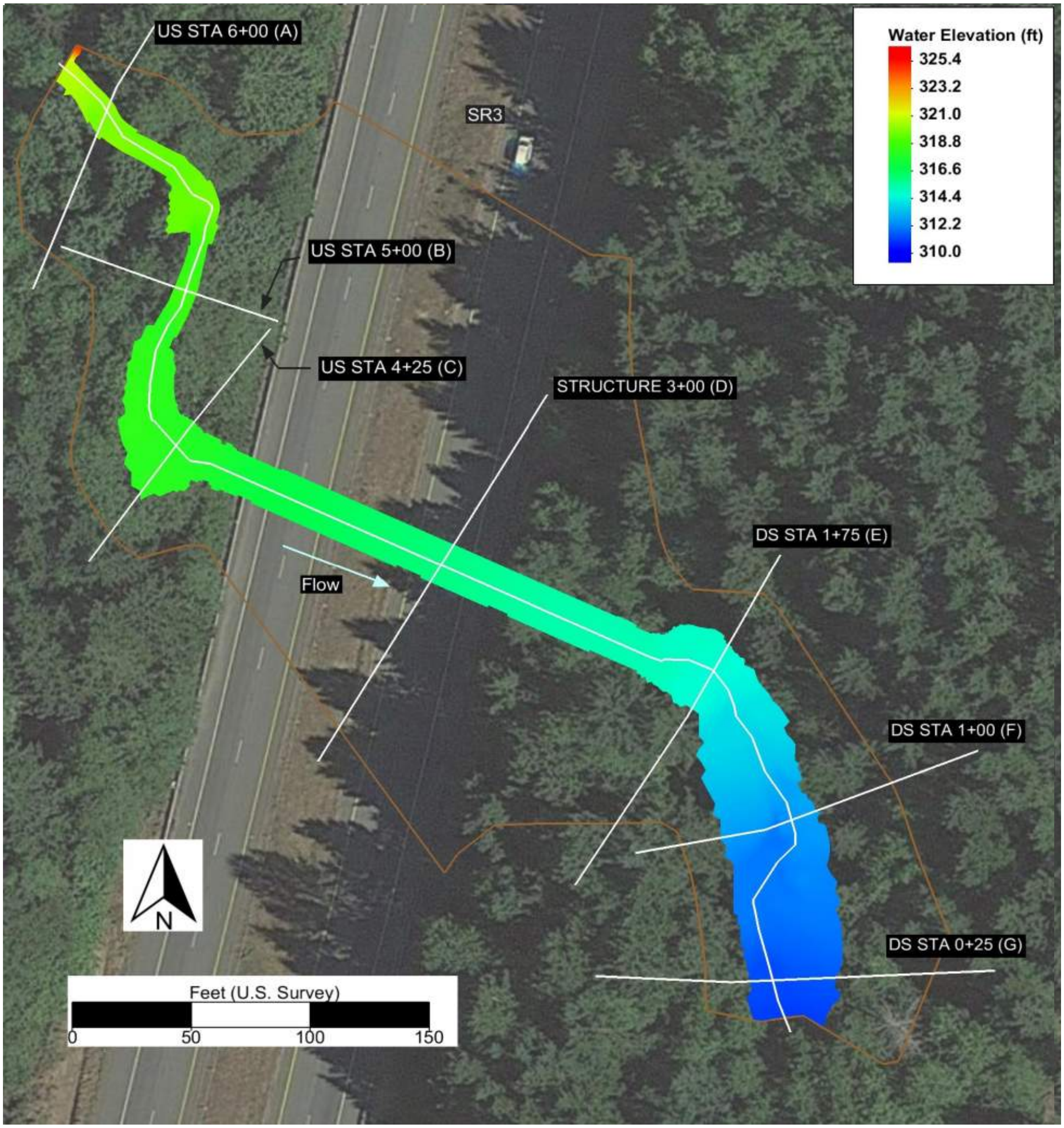


Fig H-17: Proposed Conditions 100-yr water surface elevation

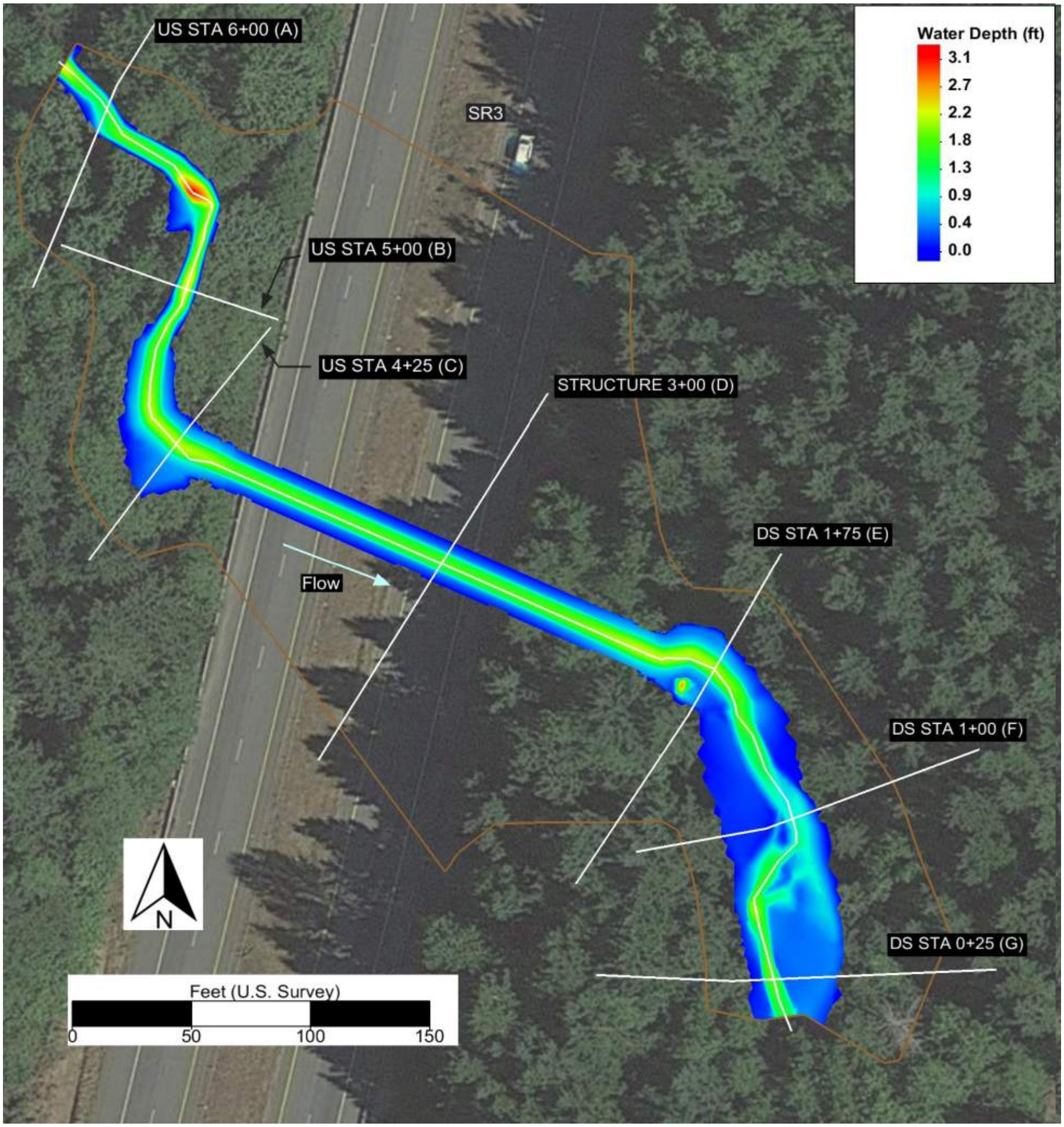


Fig H-18: Proposed Conditions 100-yr water depth

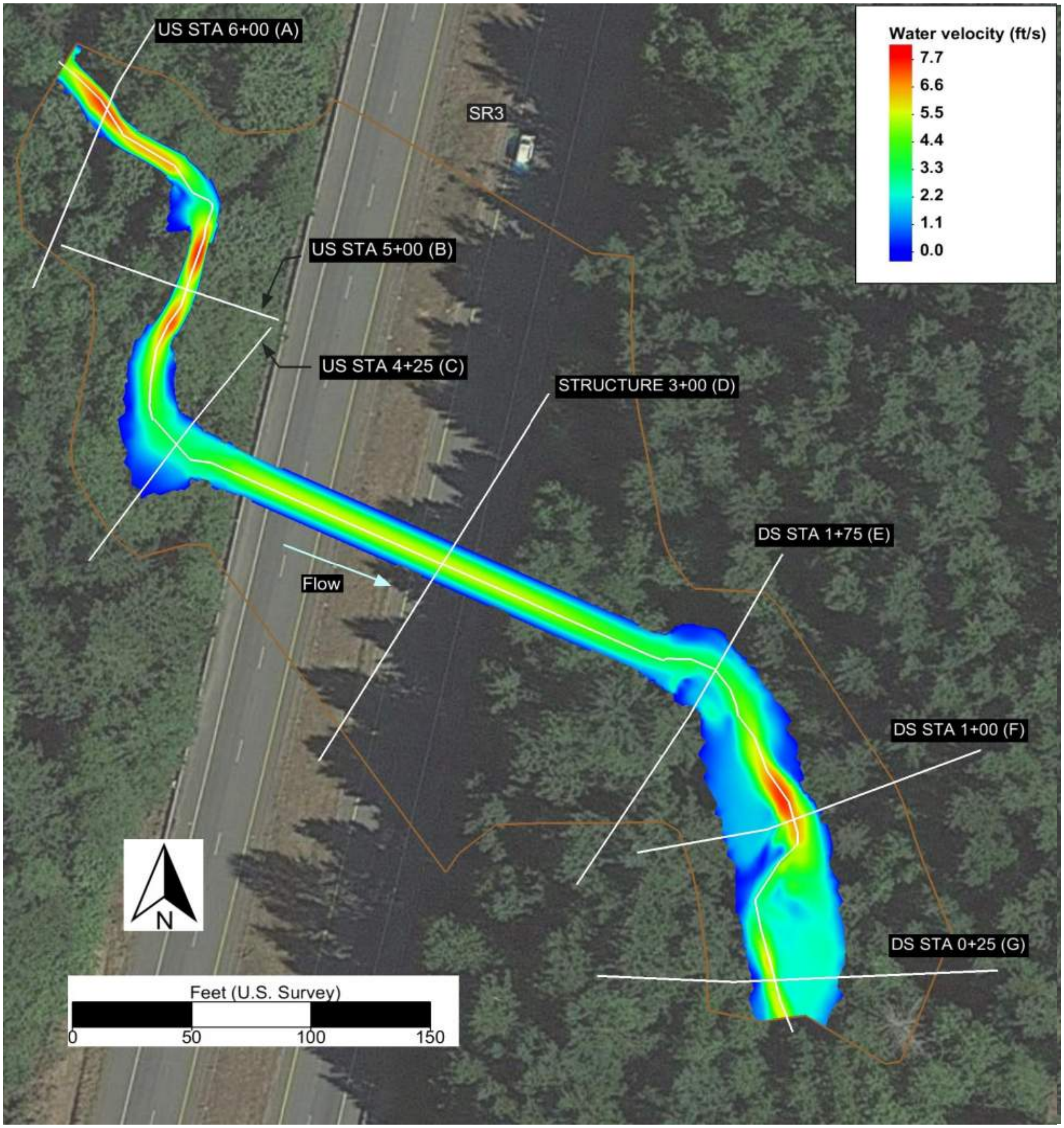


Fig H-19: Proposed Conditions 100-yr water velocity

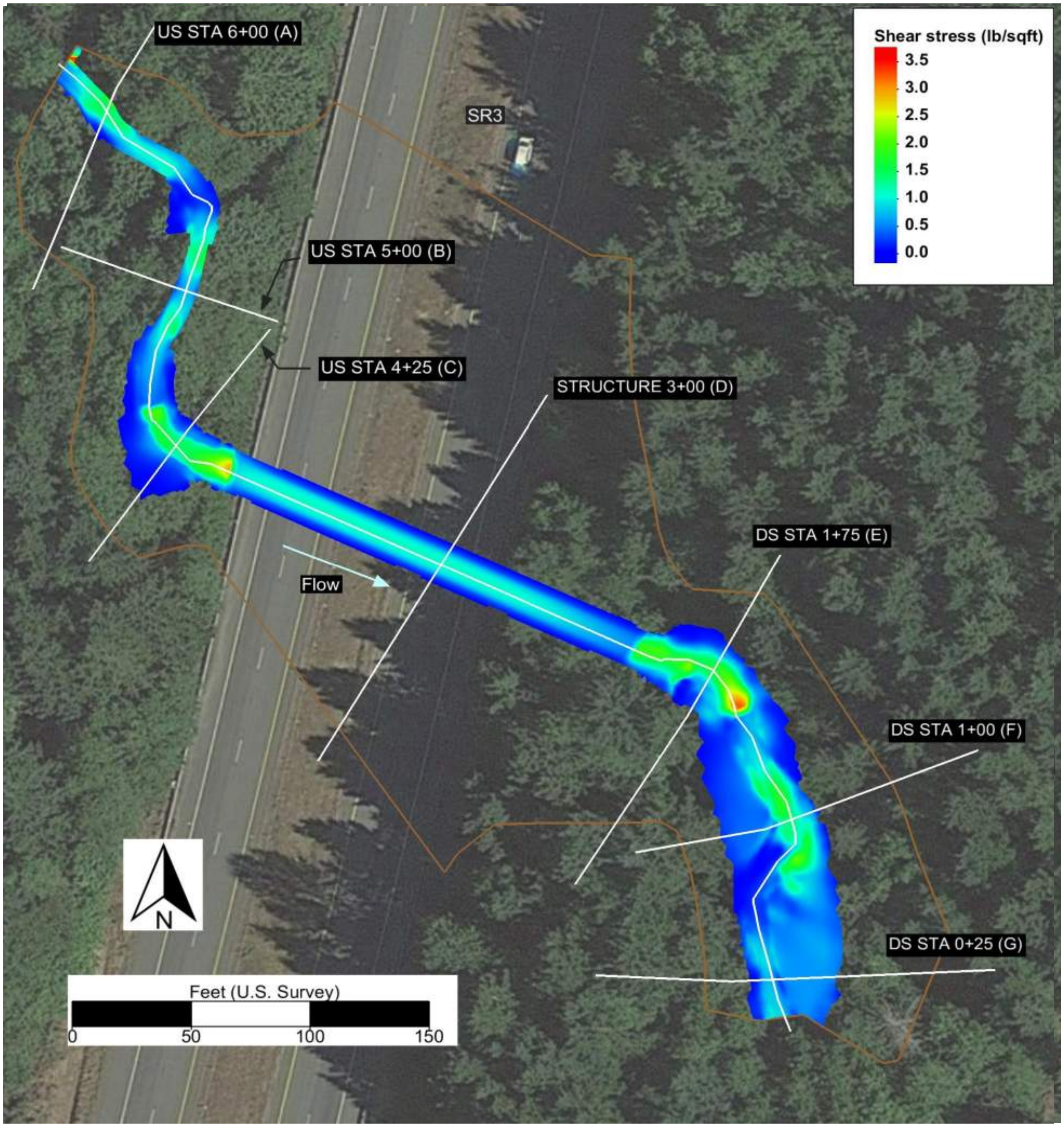


Fig H-20: Proposed Conditions 100-yr shear stress

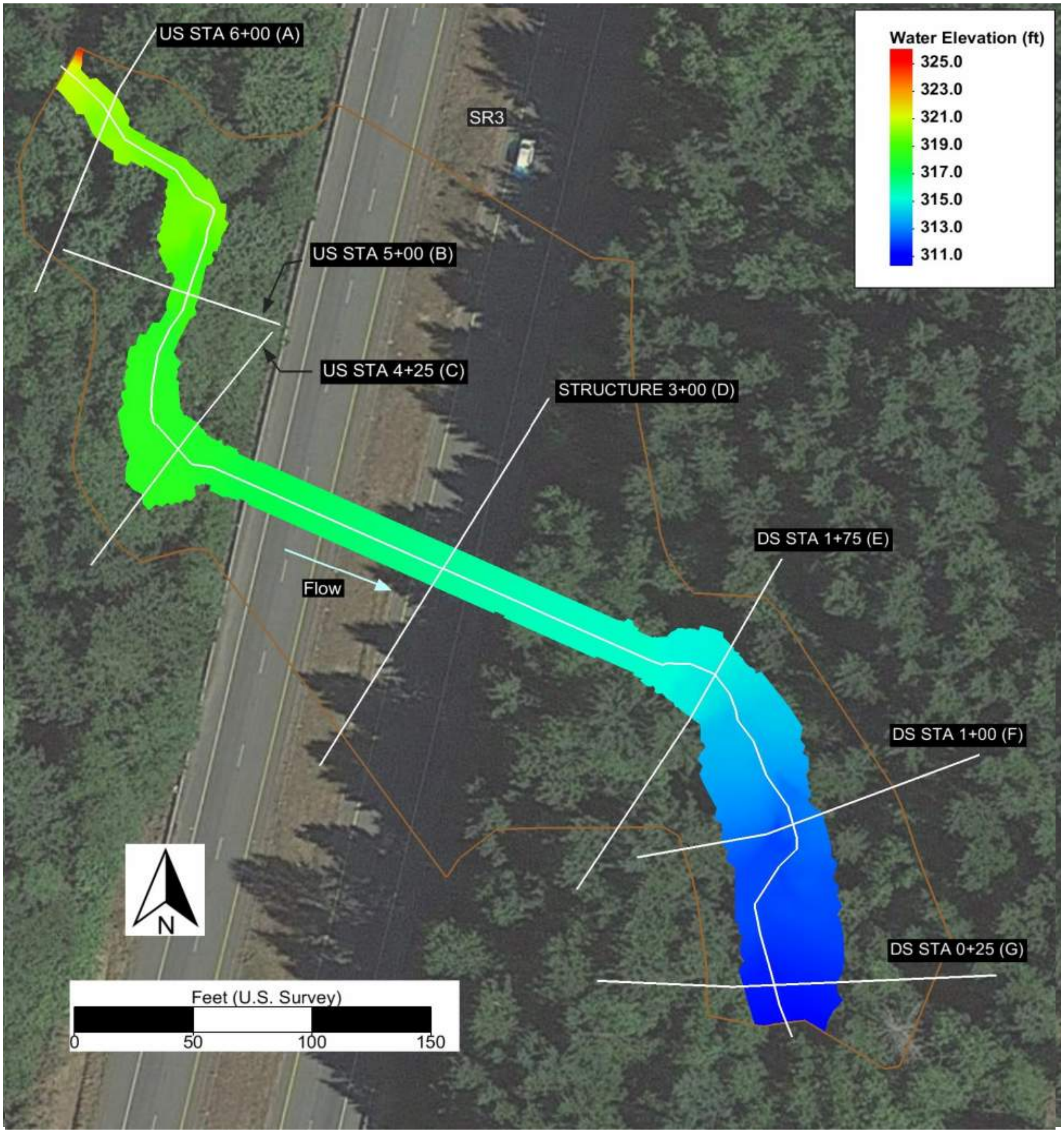


Fig H-21: Proposed Conditions 500-yr water surface elevation

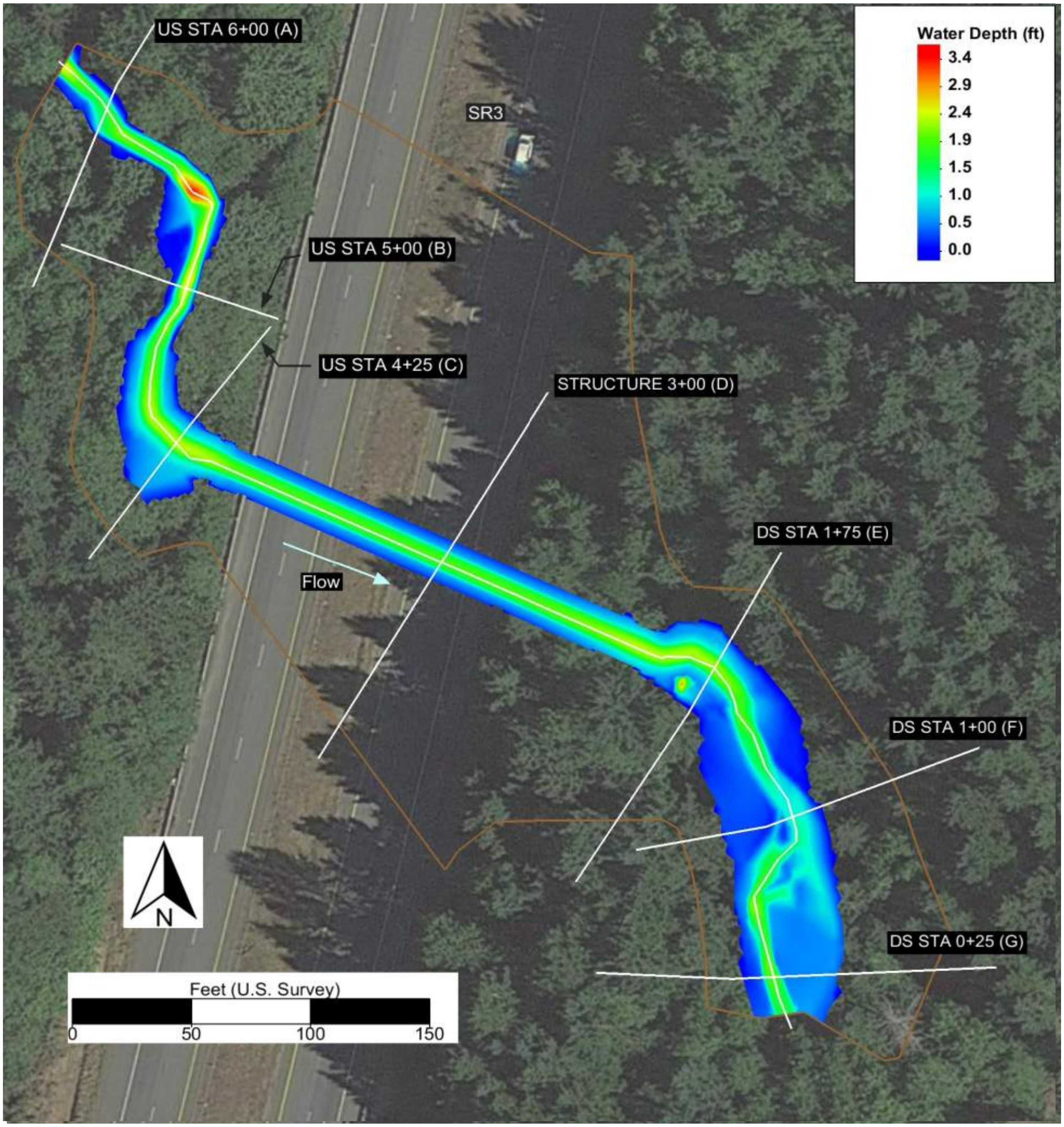


Fig H-22: Proposed Conditions 500-yr water depth

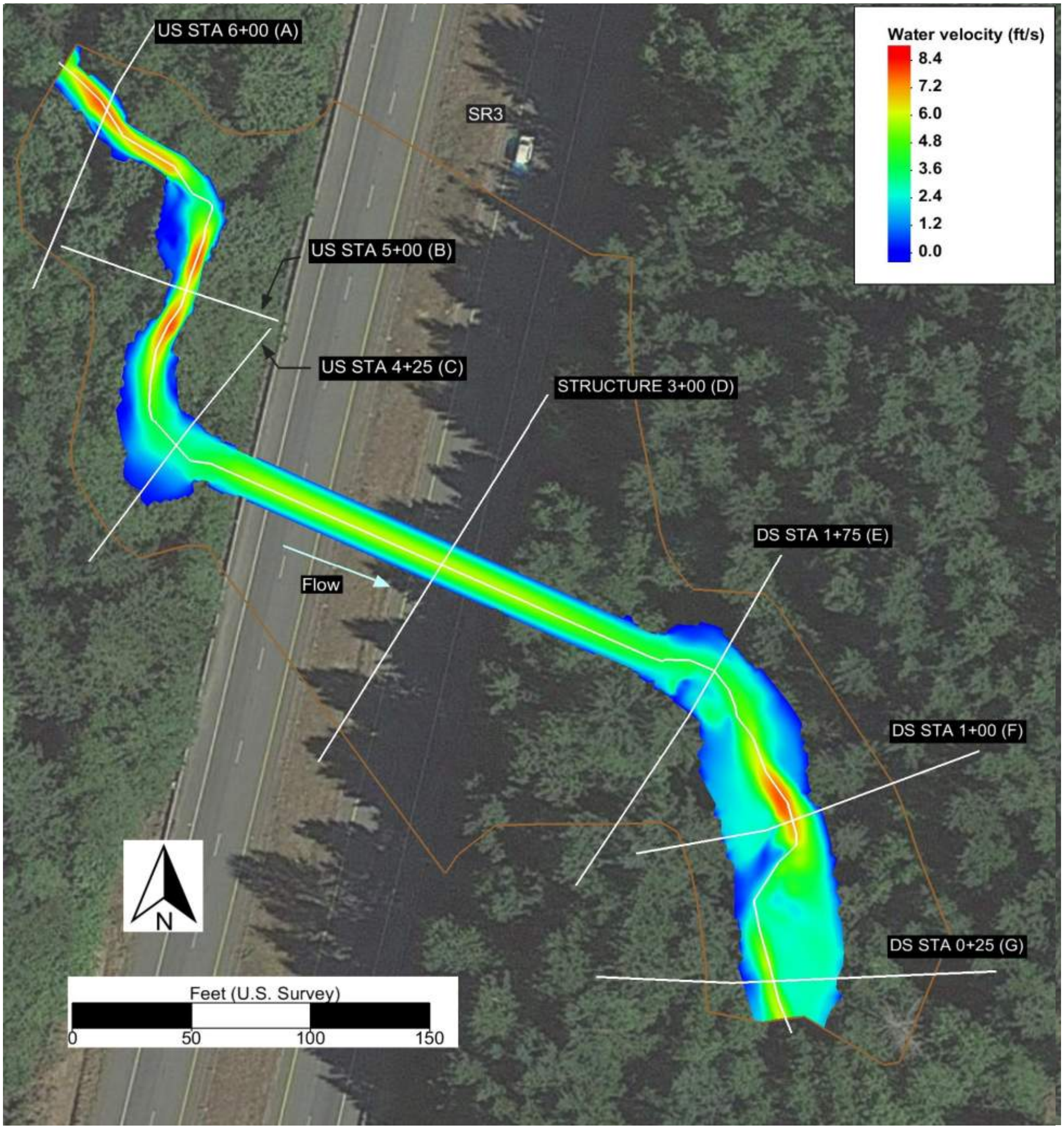


Fig H-23: Proposed Conditions 500-yr water velocity

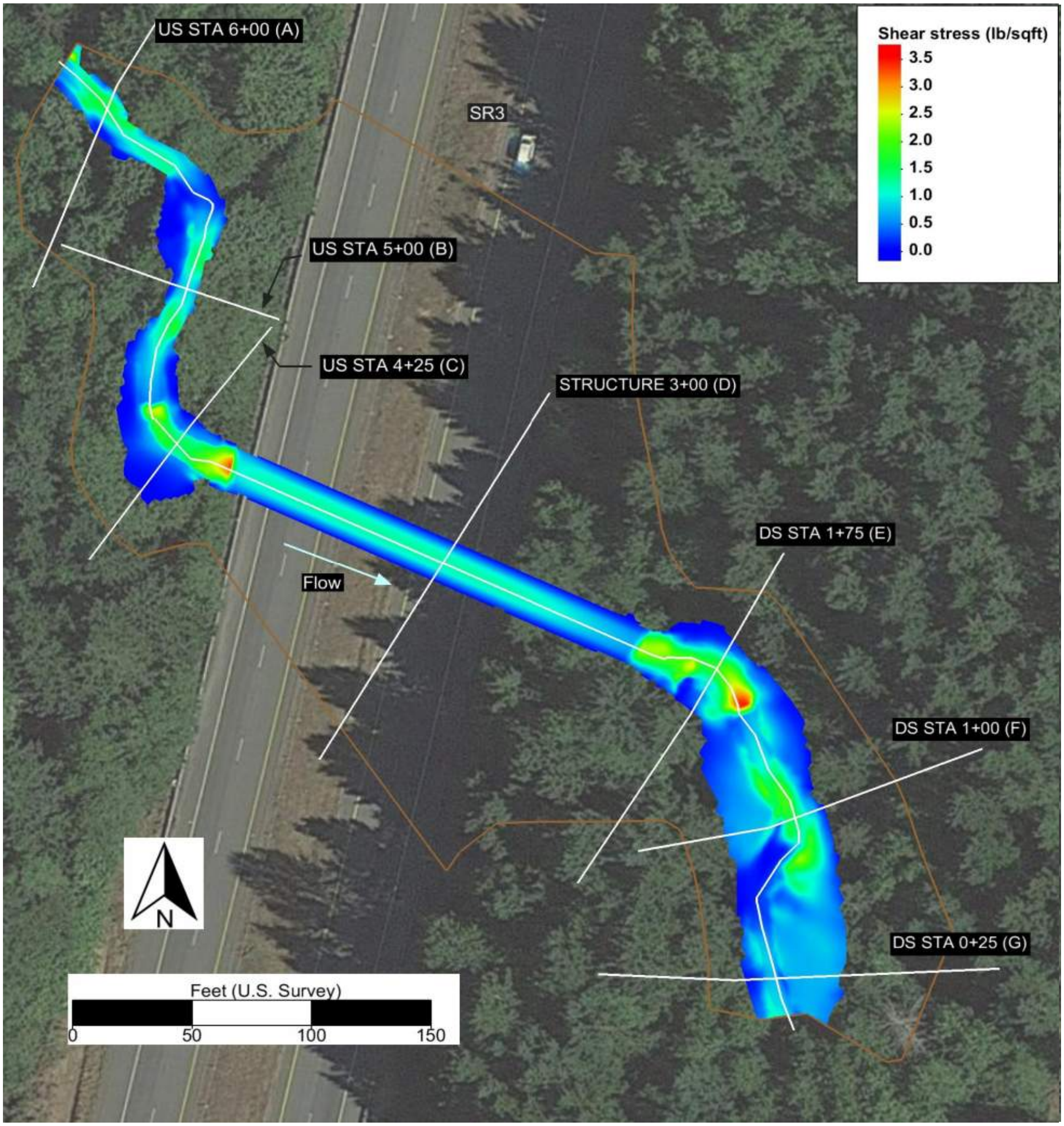


Fig H-24: Proposed Conditions 500-yr shear stress

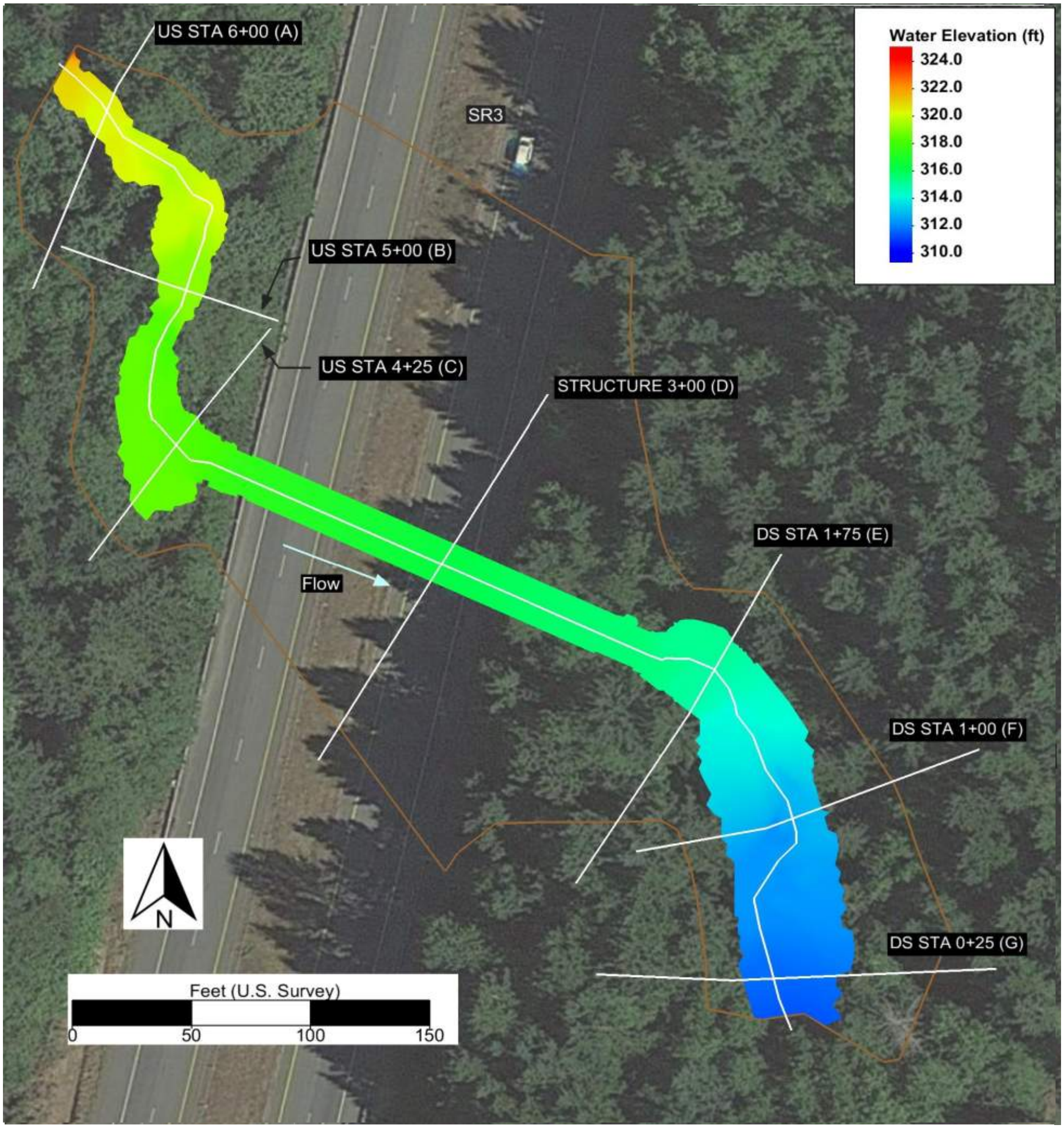


Fig H-25: Proposed Conditions 2080 100-yr water surface elevation

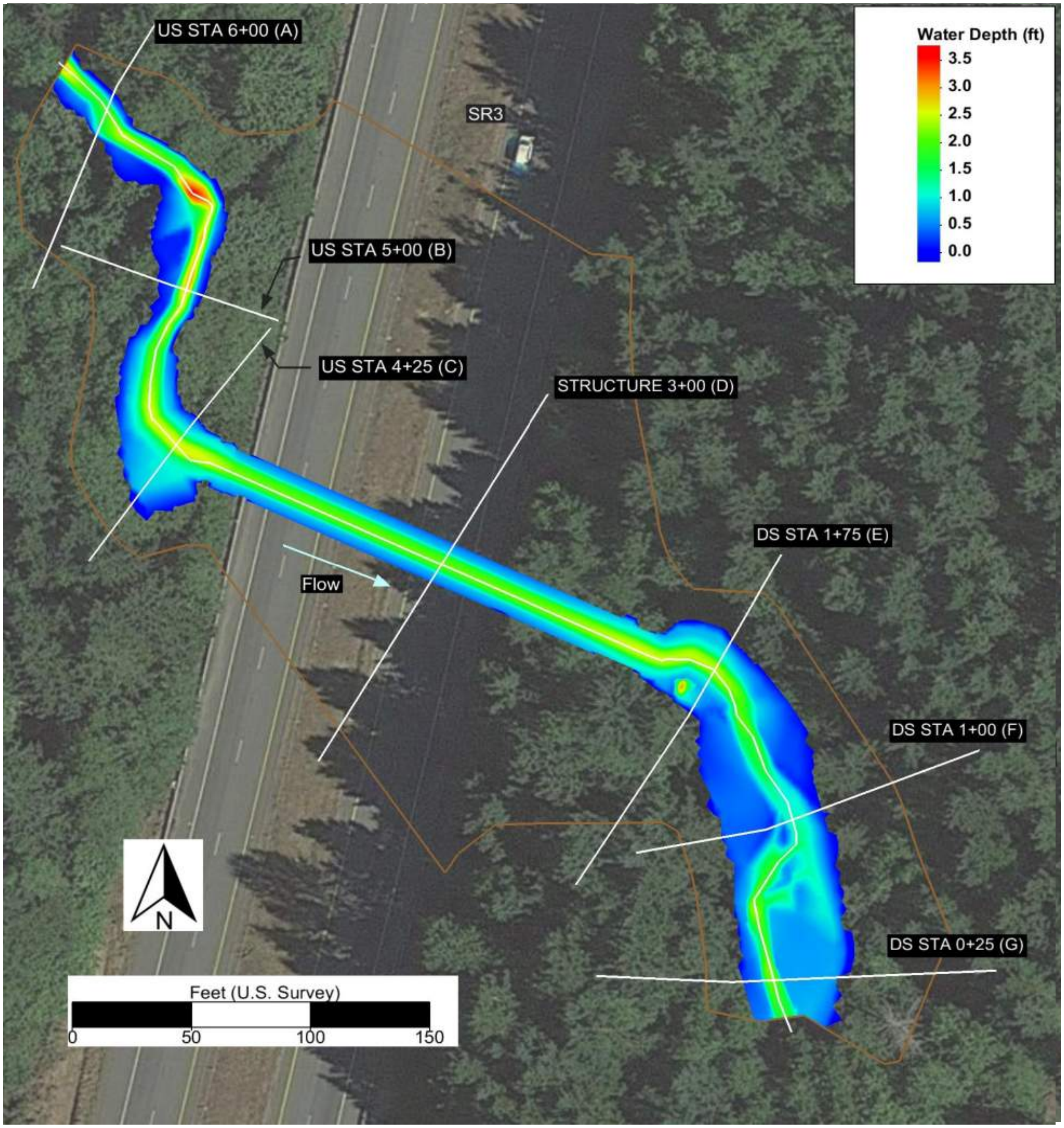


Fig H-26: Proposed Conditions 2080 100-yr water depth

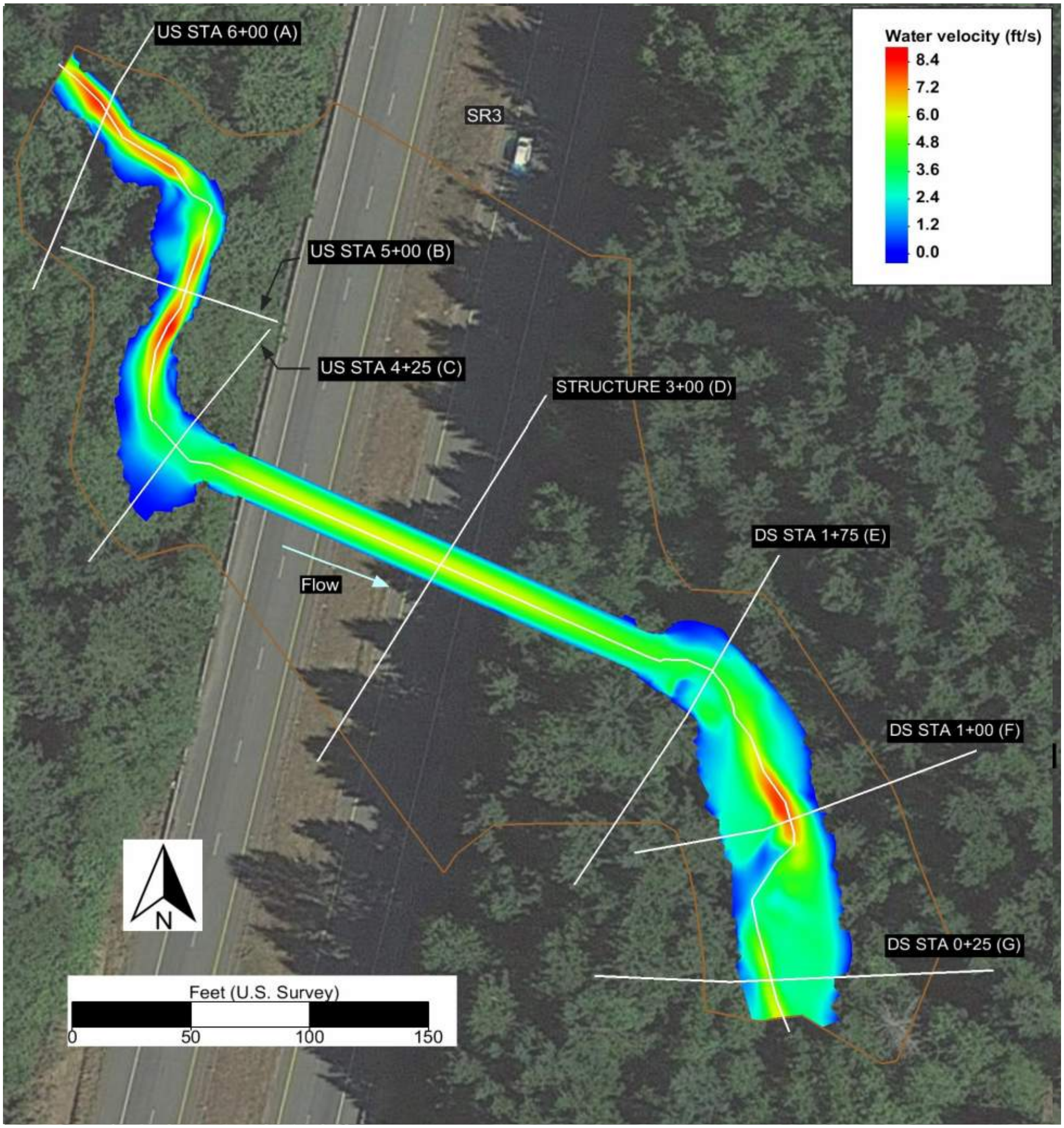


Fig H-27: Proposed Conditions 2080 100-yr velocity

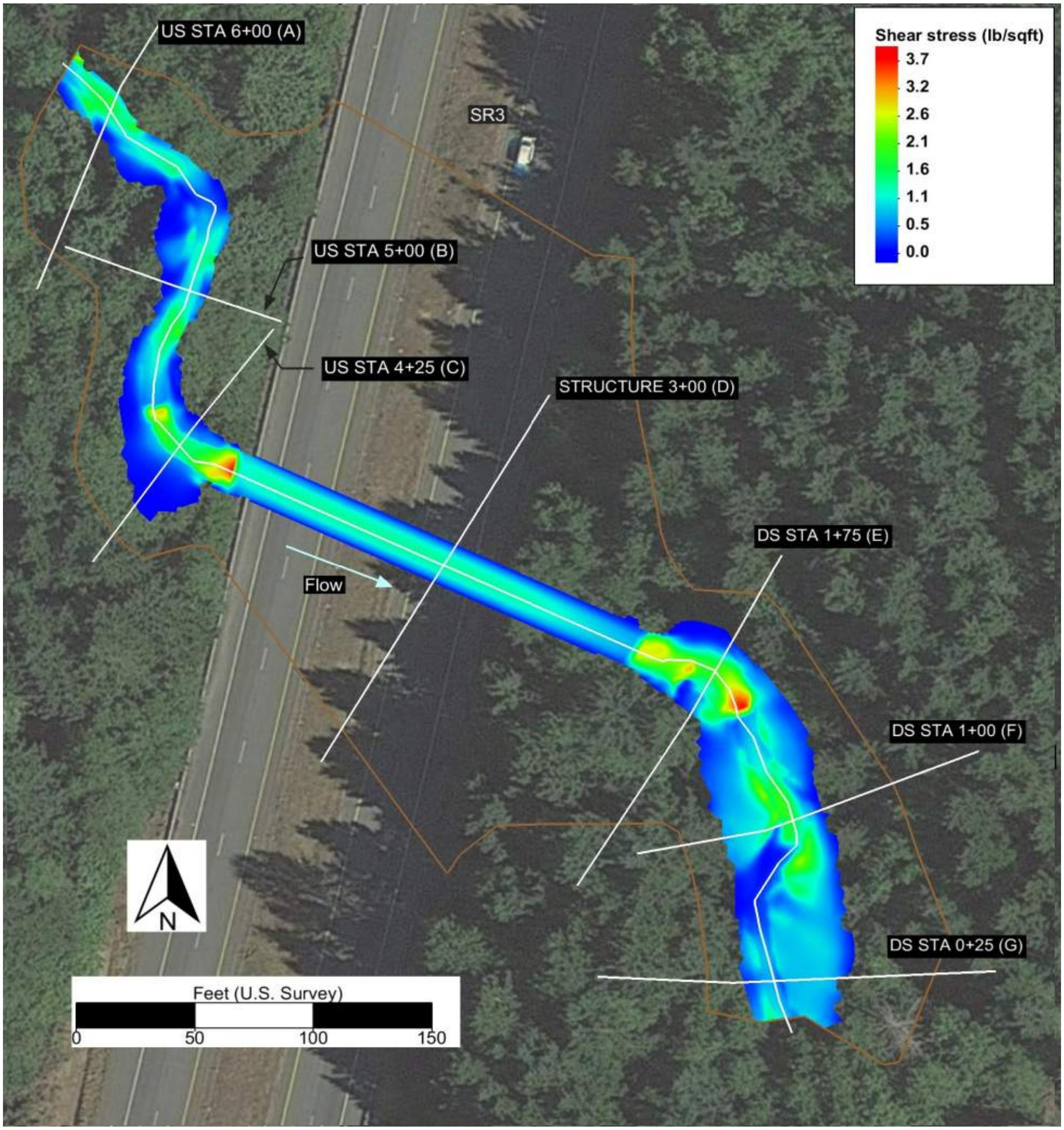
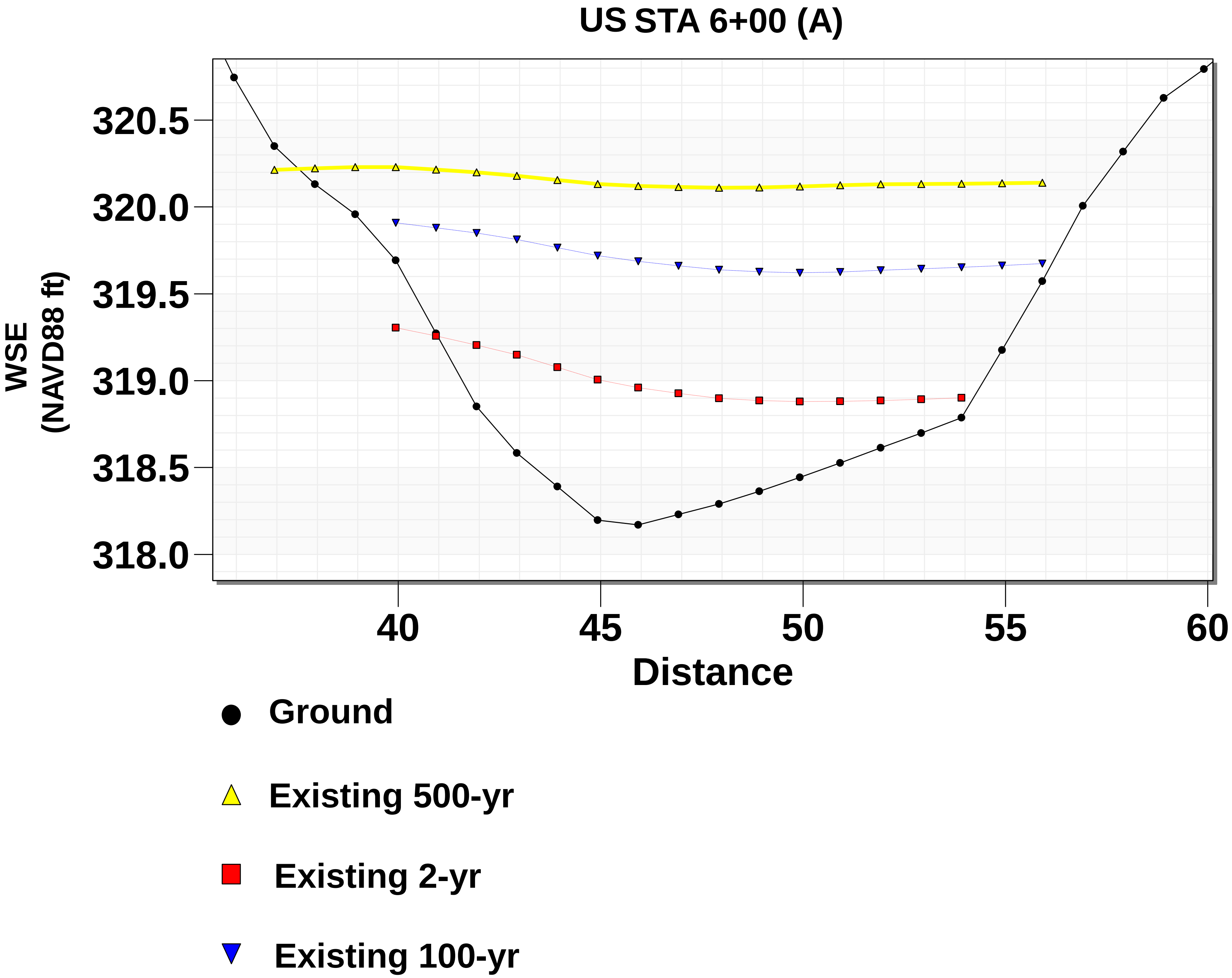
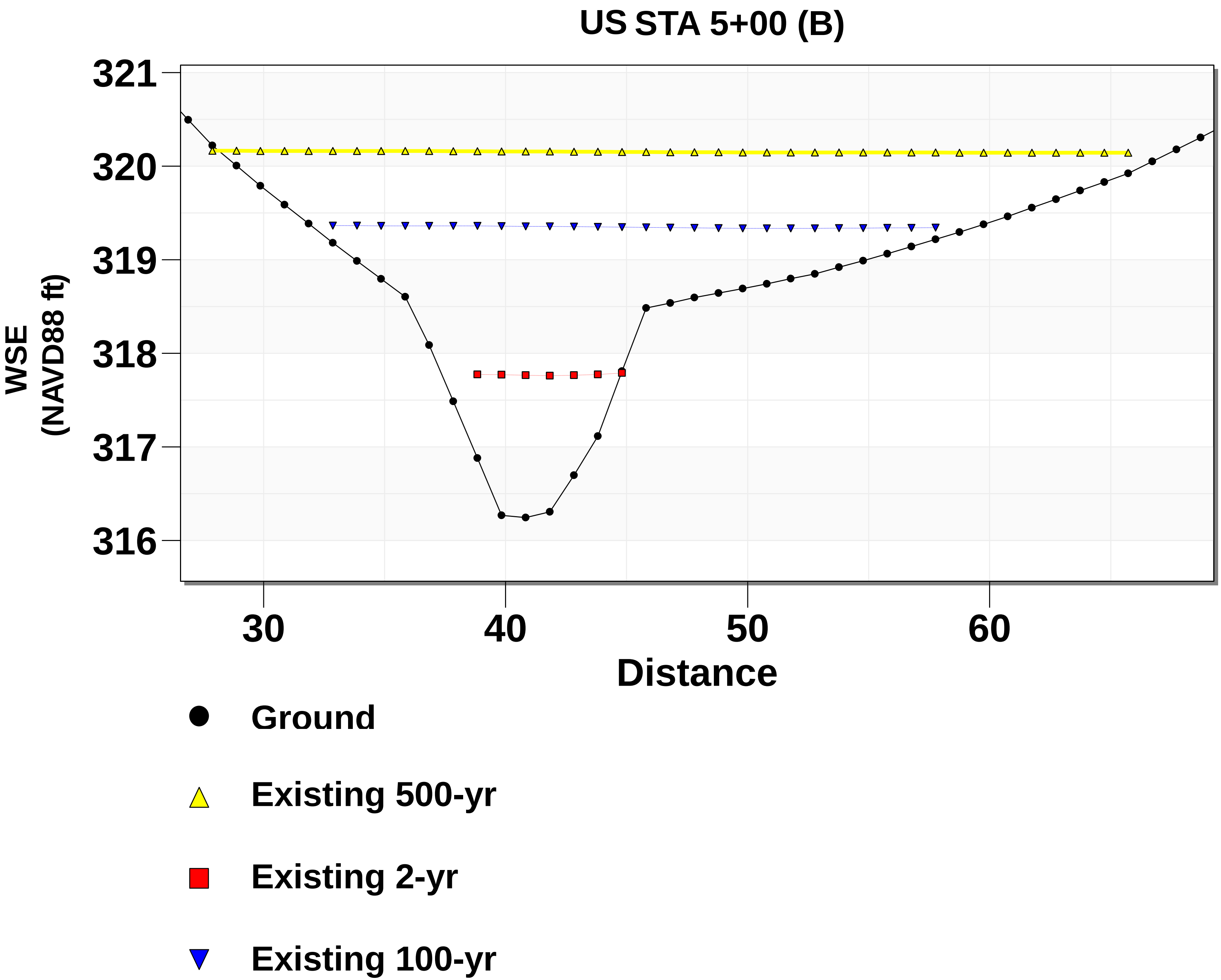


Fig H-28: Proposed Conditions 2080 100-yr shear stress

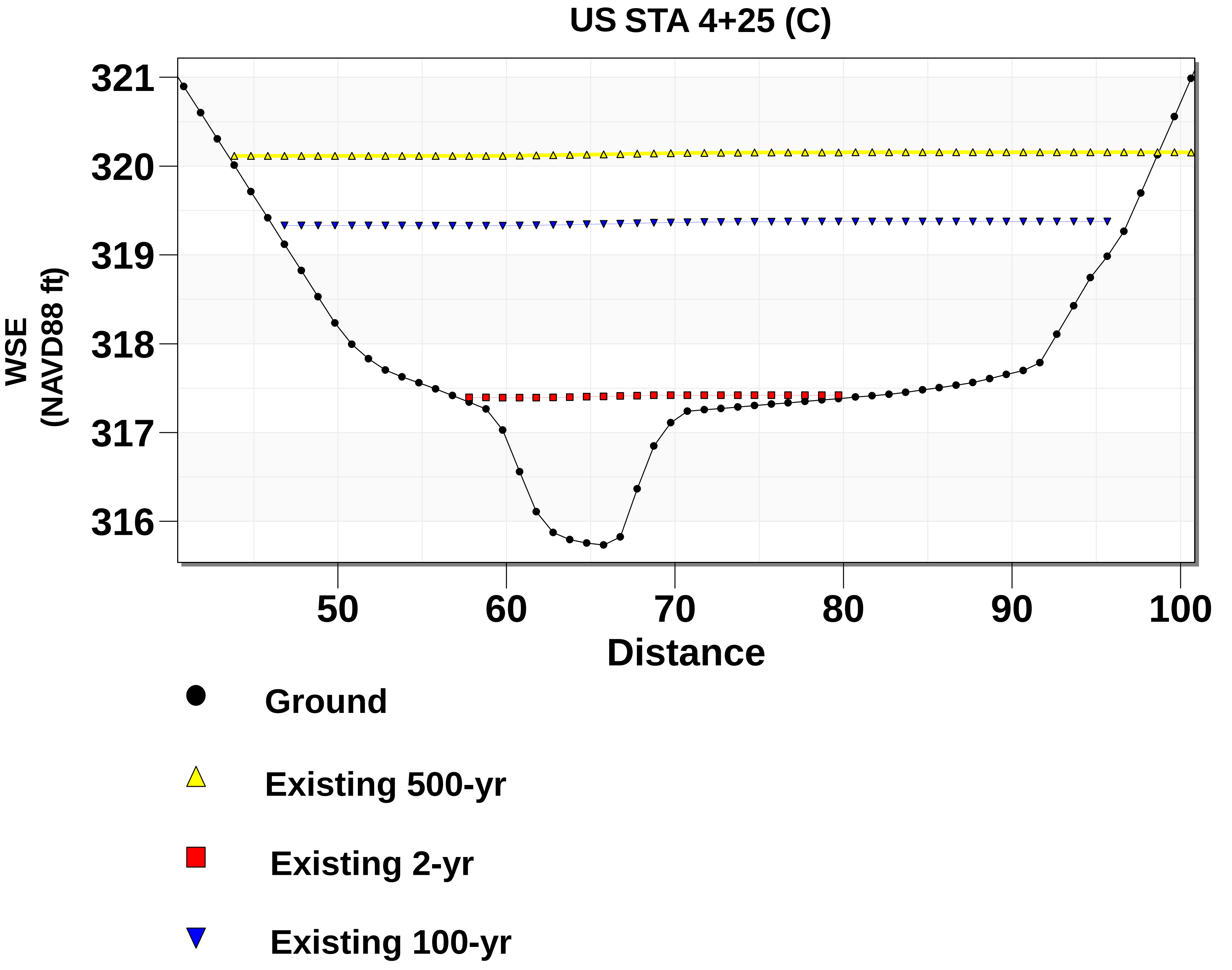
Existing WSEs



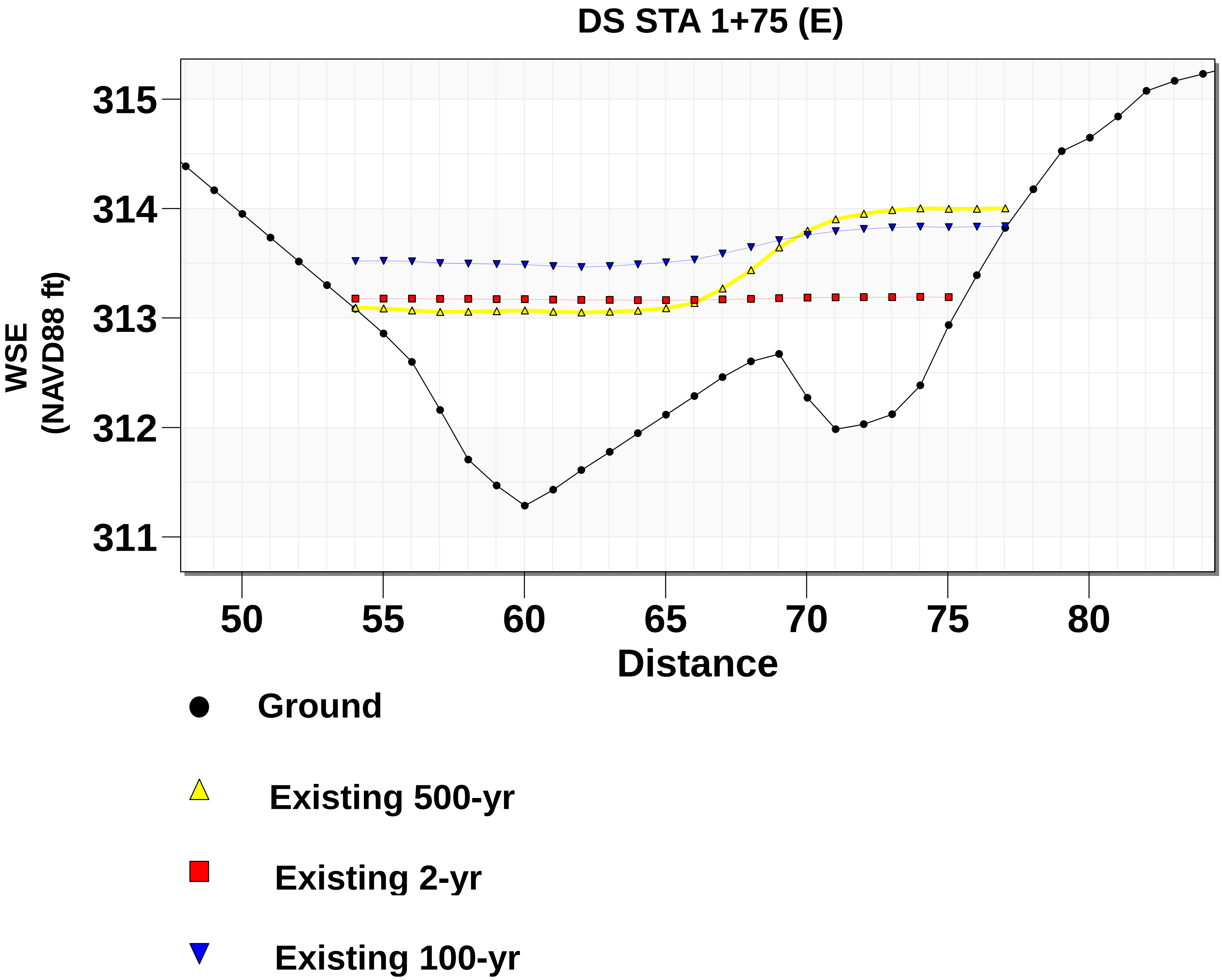
US STA 6+00 (A)
WSE
(NAVD88 ft)
320.5
320.0
319.5
319.0
318.5
318.0
40
45
50
55
60
Distance
Ground
Existing 500-yr
Existing 2-yr
Existing 100-yr



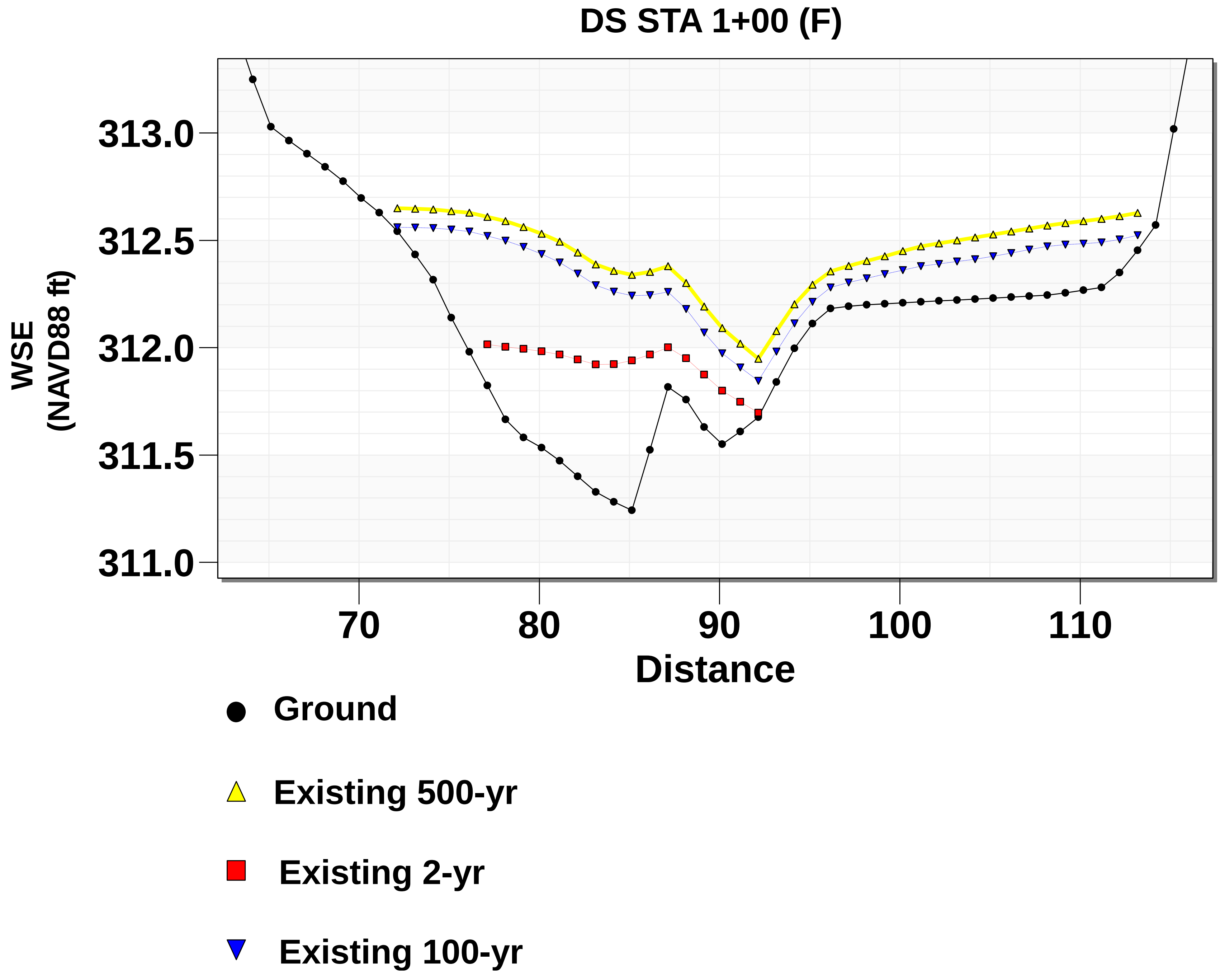
US STA 5+00 (B)
WSE
(NAVD88 ft)
321
320
319
318
317
316
30
40
50
60
Distance
Ground
Existing 500-yr
Existing 2-yr
Existing 100-yr

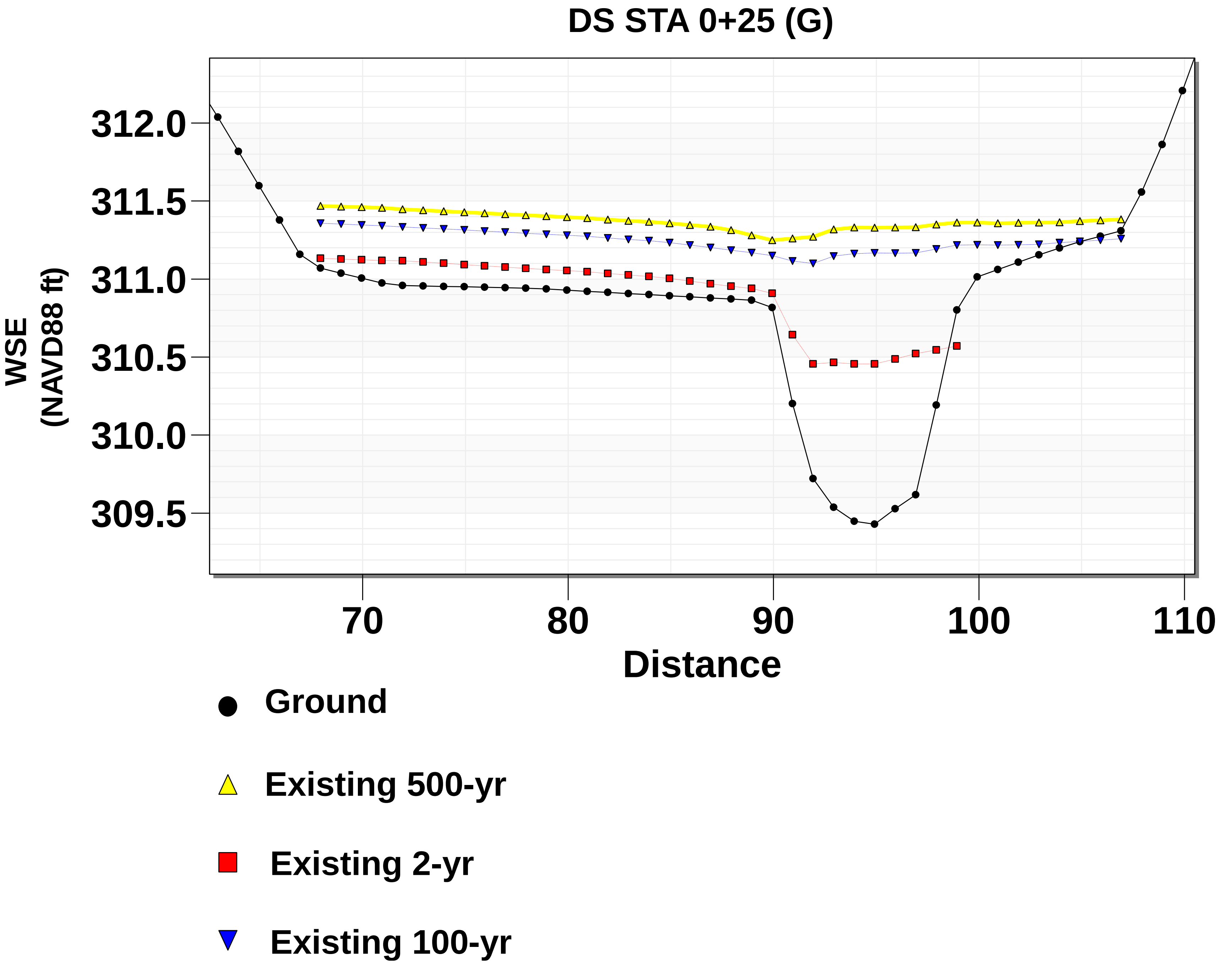


US STA 4+25 (C)
321
320
319
318
317
316
WSE
(NAVD88 ft)
50
60
70
80
90
100
Distance
Ground
Existing 500-yr
Existing 2-yr
Existing 100-yr

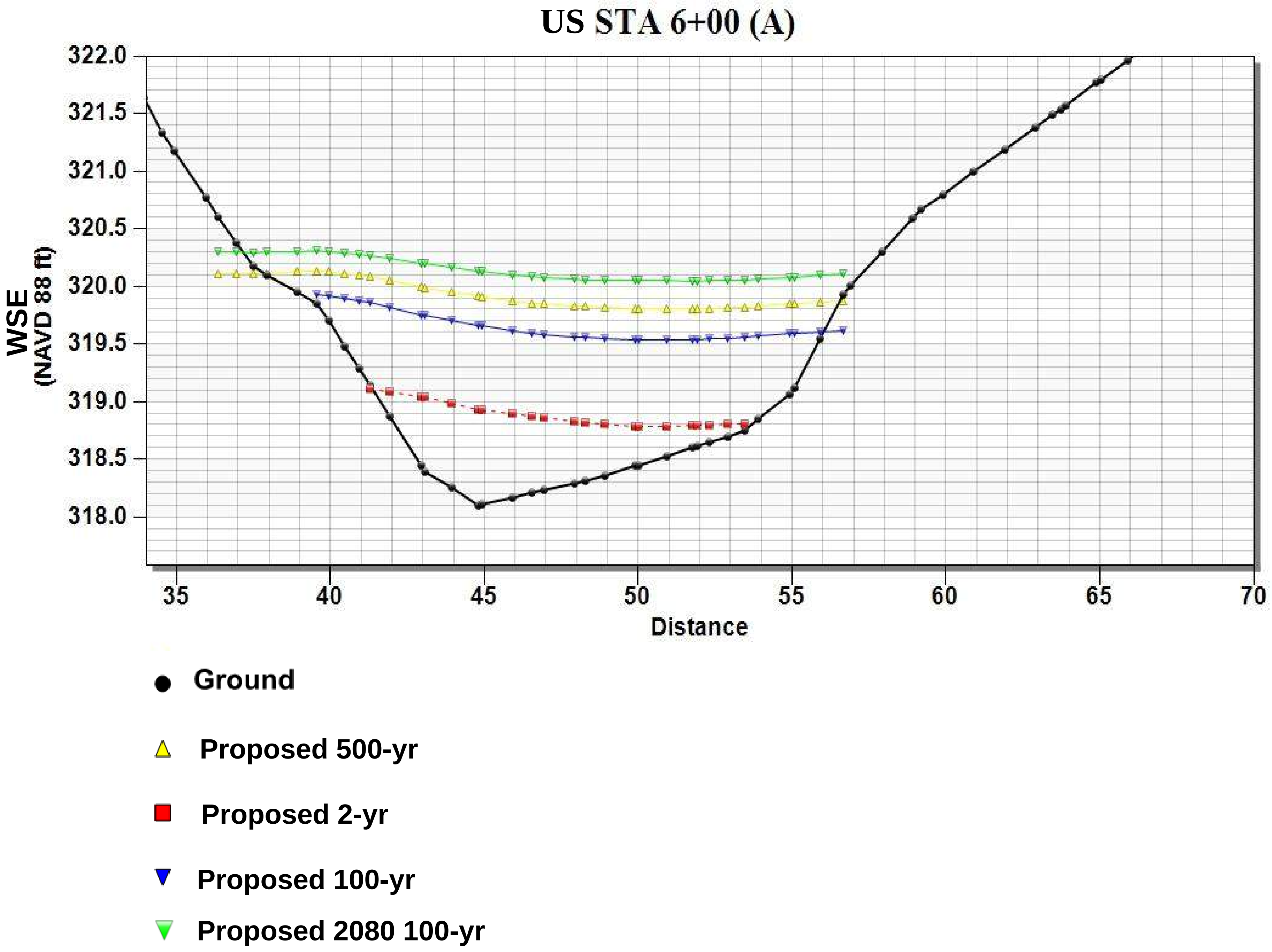


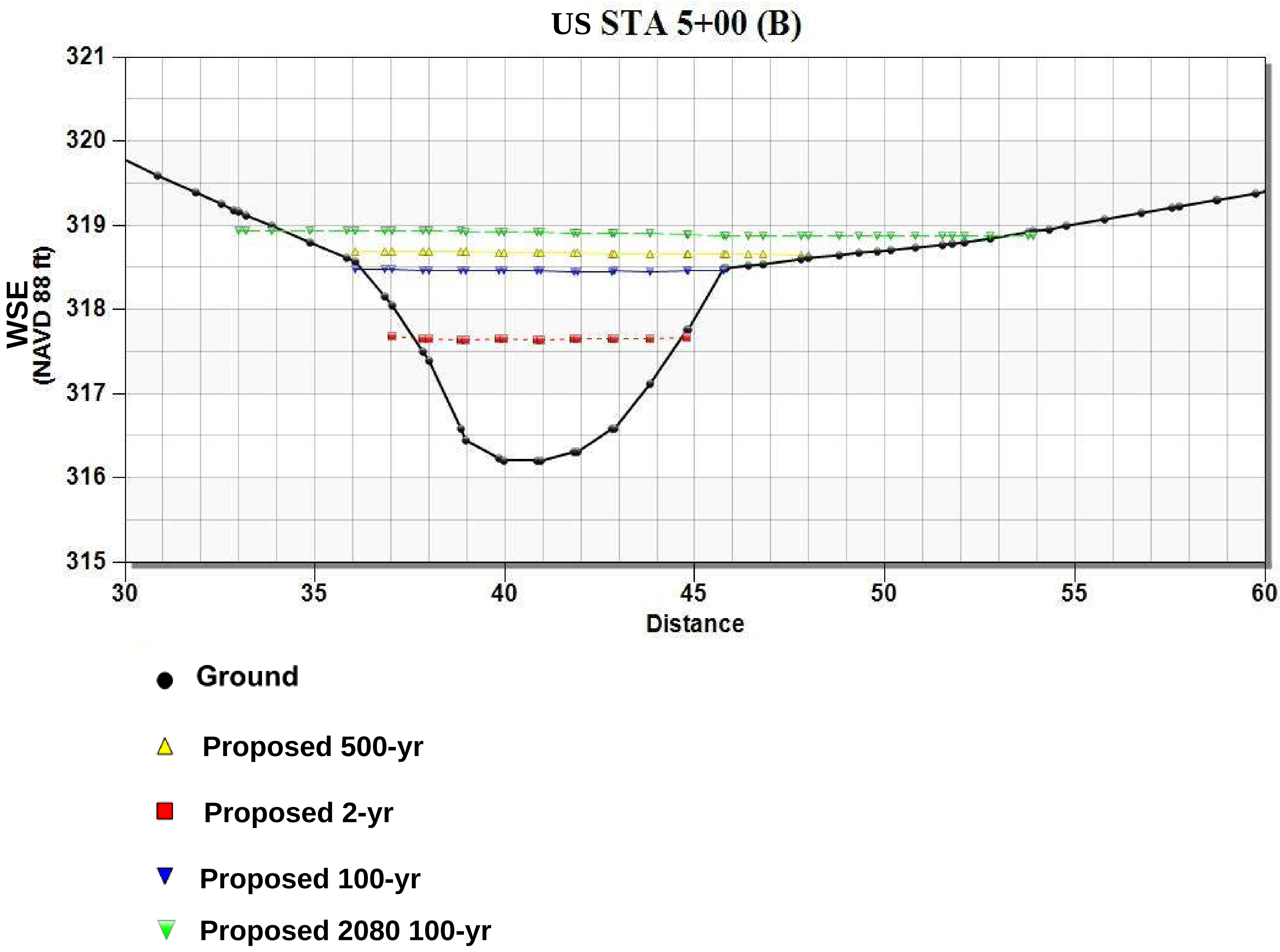
DS STA 1+75 (E)
WSE
(NAVD88 ft)
315
314
313
312
311
50
55
60
65
70
75
80
Distance
Ground
Existing 500-yr
Existing 2-yr
Existing 100-yr


DS STA 1+00 (F)
WSE
(NAVD88 ft)
313.0
312.5
312.0
311.5
311.0
70
80
90
100
110
Distance
Ground
Existing 500-yr
Existing 2-yr
Existing 100-yr


DS STA 0+25 (G)
WSE
(NAVD88 ft)
312.0
311.5
311.0
310.5
310.0
309.5
70
80
90
100
110
Distance
Ground
Existing 500-yr
Existing 2-yr
Existing 100-yr

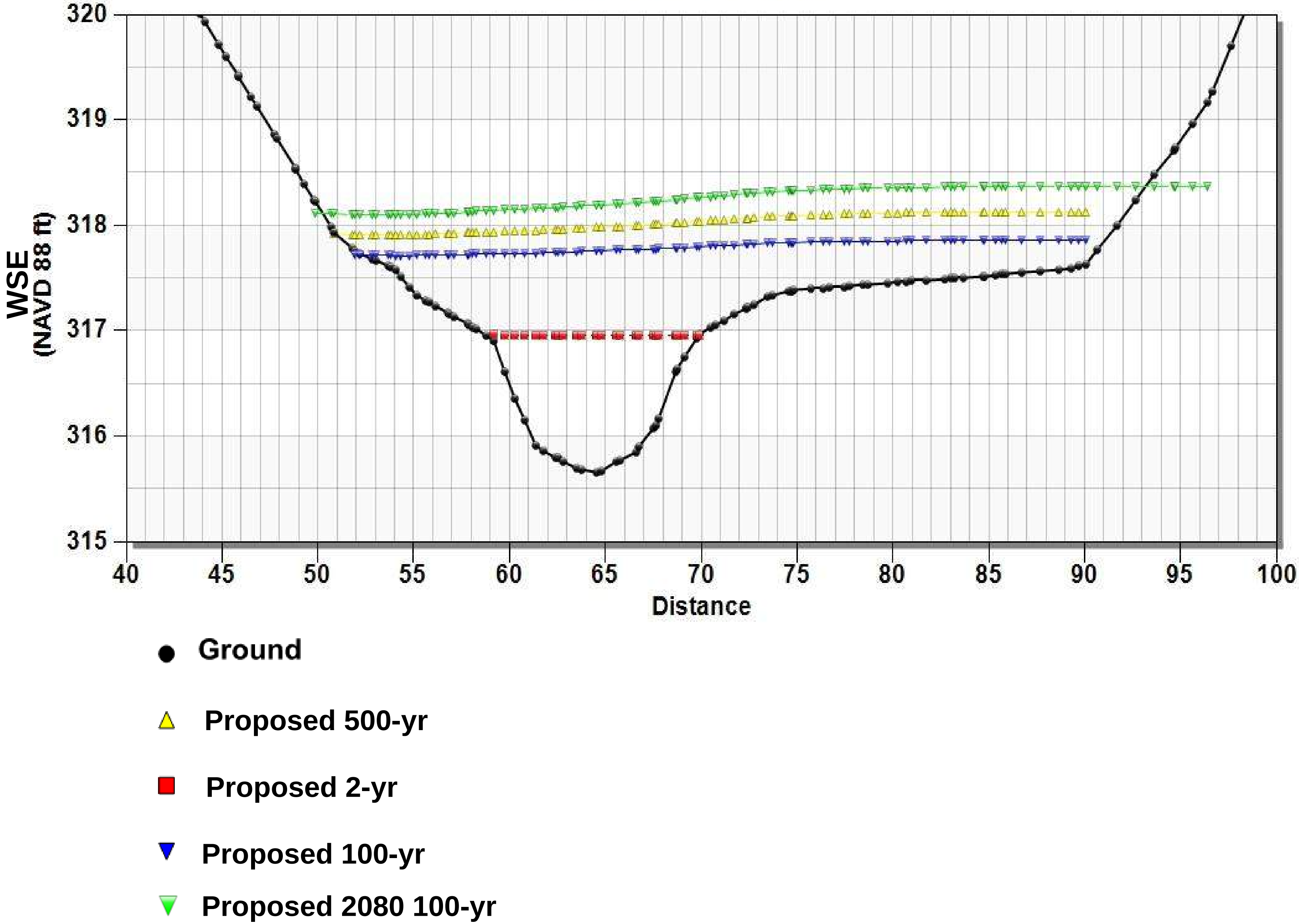
Proposed WSEs


US STA 6+00 (A)
WSE
(NAVD 88 ft)
322.0
321.5
321.0
320.5
320.0
319.5
319.0
318.5
318.0
35
40
45
50
55
60
65
70
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr

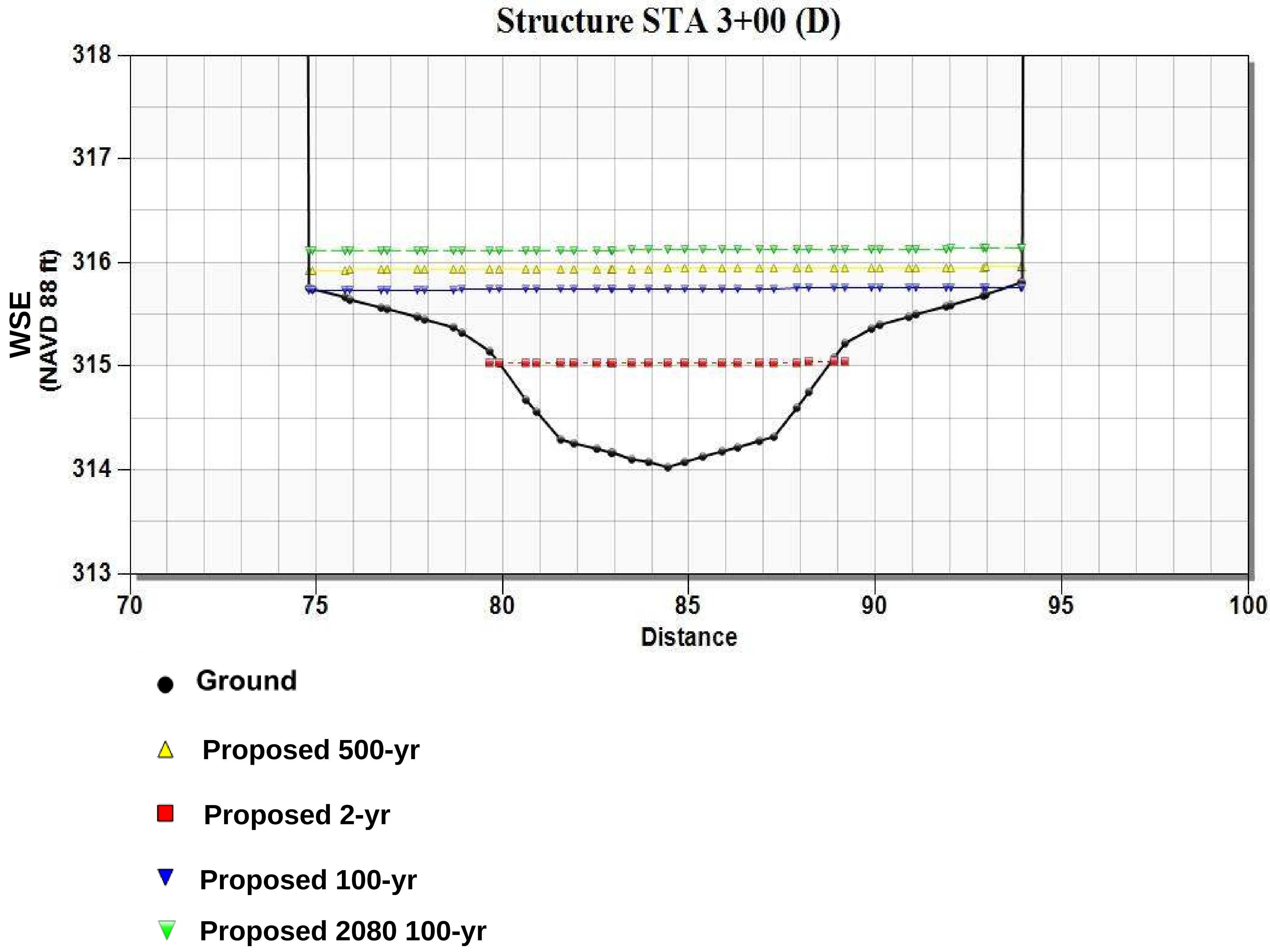


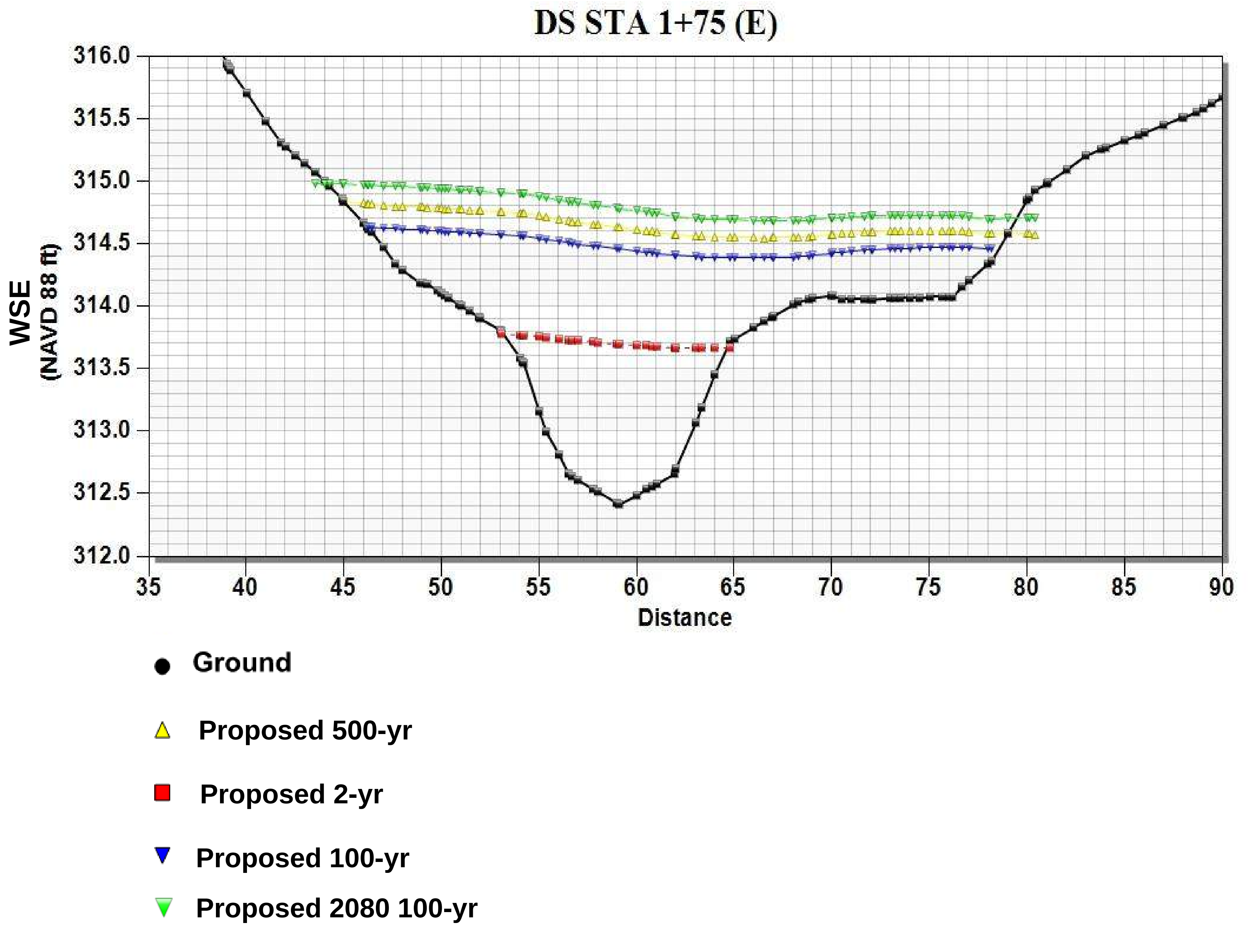
US STA 5+00 (B)
WSE (NAVD 88 ft)
321
320
319
318
317
316
315
30
35
40
45
50
55
60
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr

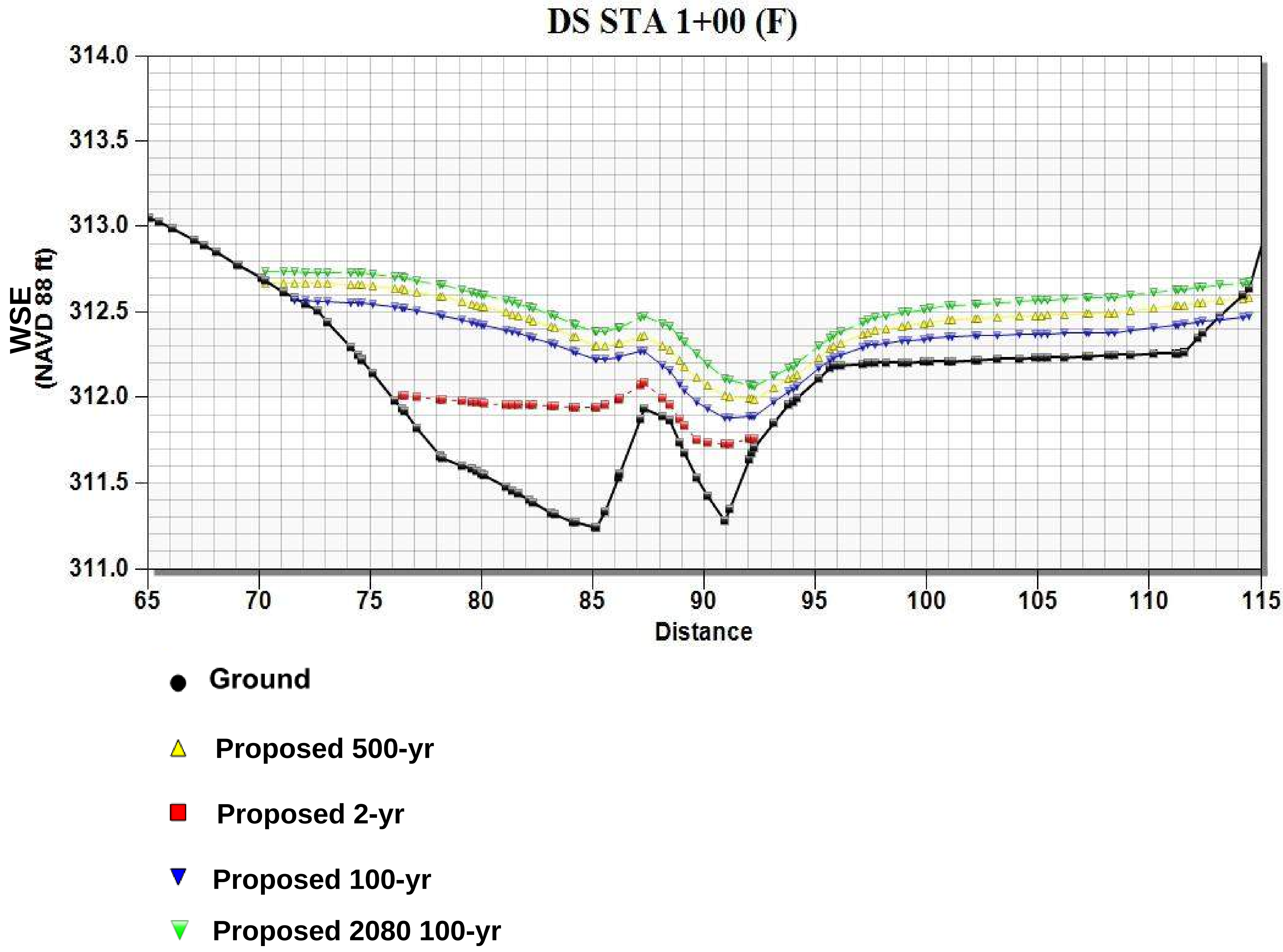
US STA 4+25 (C)

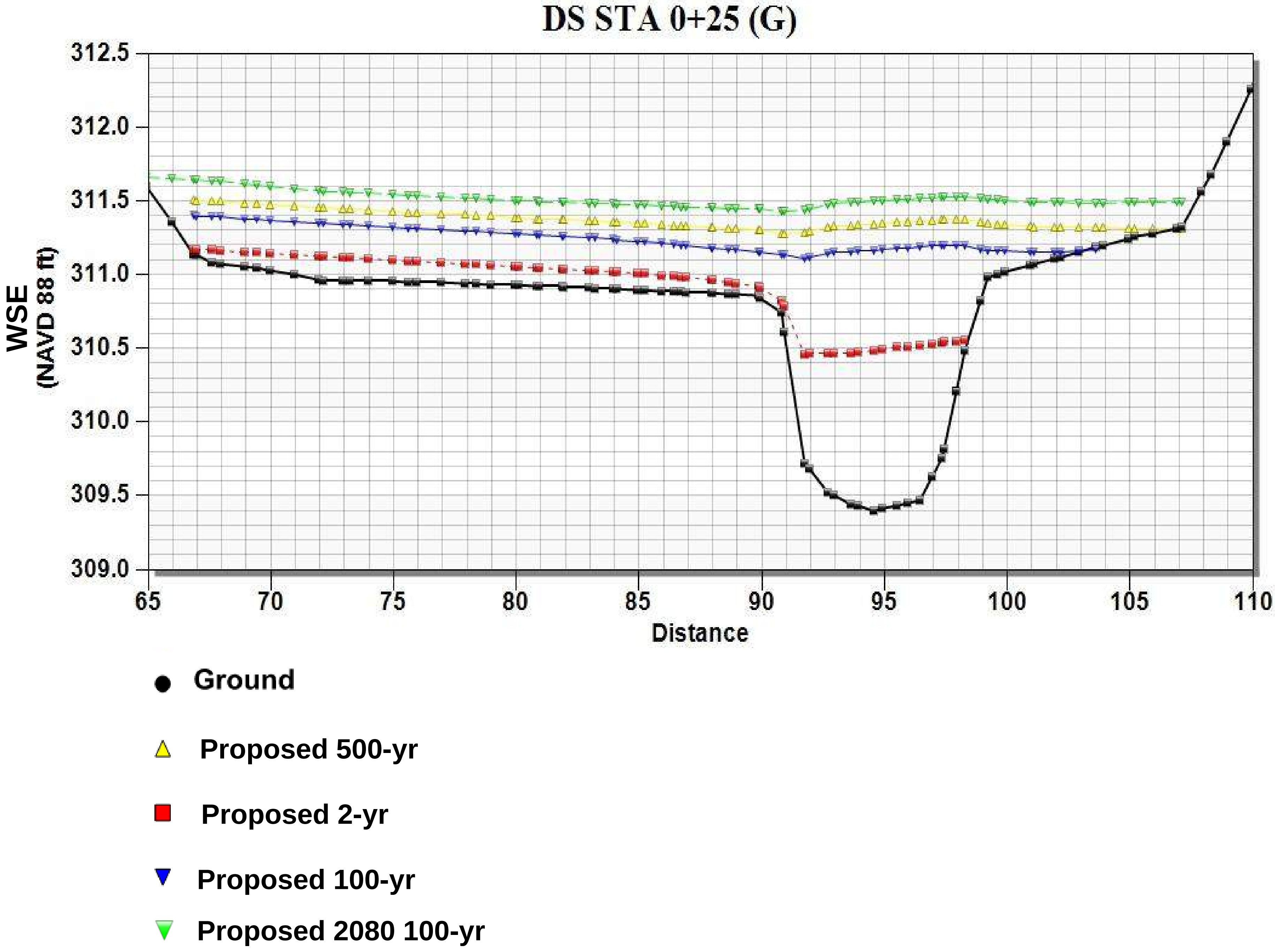


WSE
(NAVD 88 ft)
320
319
318
317
316
315
40
45
50
55
60
65
70
75
80
85
90
95
100
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr


Structure STA 3+00 (D)
WSE
(NAVD 88 ft)
318
317
316
315
314
313
70
75
80
85
90
95
100
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr


DS STA 1+75 (E)
WSE
(NAVD 88 ft)
316.0
315.5
315.0
314.5
314.0
313.5
313.0
312.5
312.0
35
40
45
50
55
60
65
70
75
80
85
90
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr


DS STA 1+00 (F)
WSE
(NAVD 88 ft)
314.0
313.5
313.0
312.5
312.0
311.5
311.0
65
70
75
80
85
90
95
100
105
110
115
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr


DS STA 0+25 (G)
WSE
(NAVD 88 ft)
312.5
312.0
311.5
311.0
310.5
310.0
309.5
309.0
65
70
75
80
85
90
95
100
105
110
Distance
Ground
Proposed 500-yr
Proposed 2-yr
Proposed 100-yr
Proposed 2080 100-yr

Appendix I: SRH-2D Model Stability and Continuity

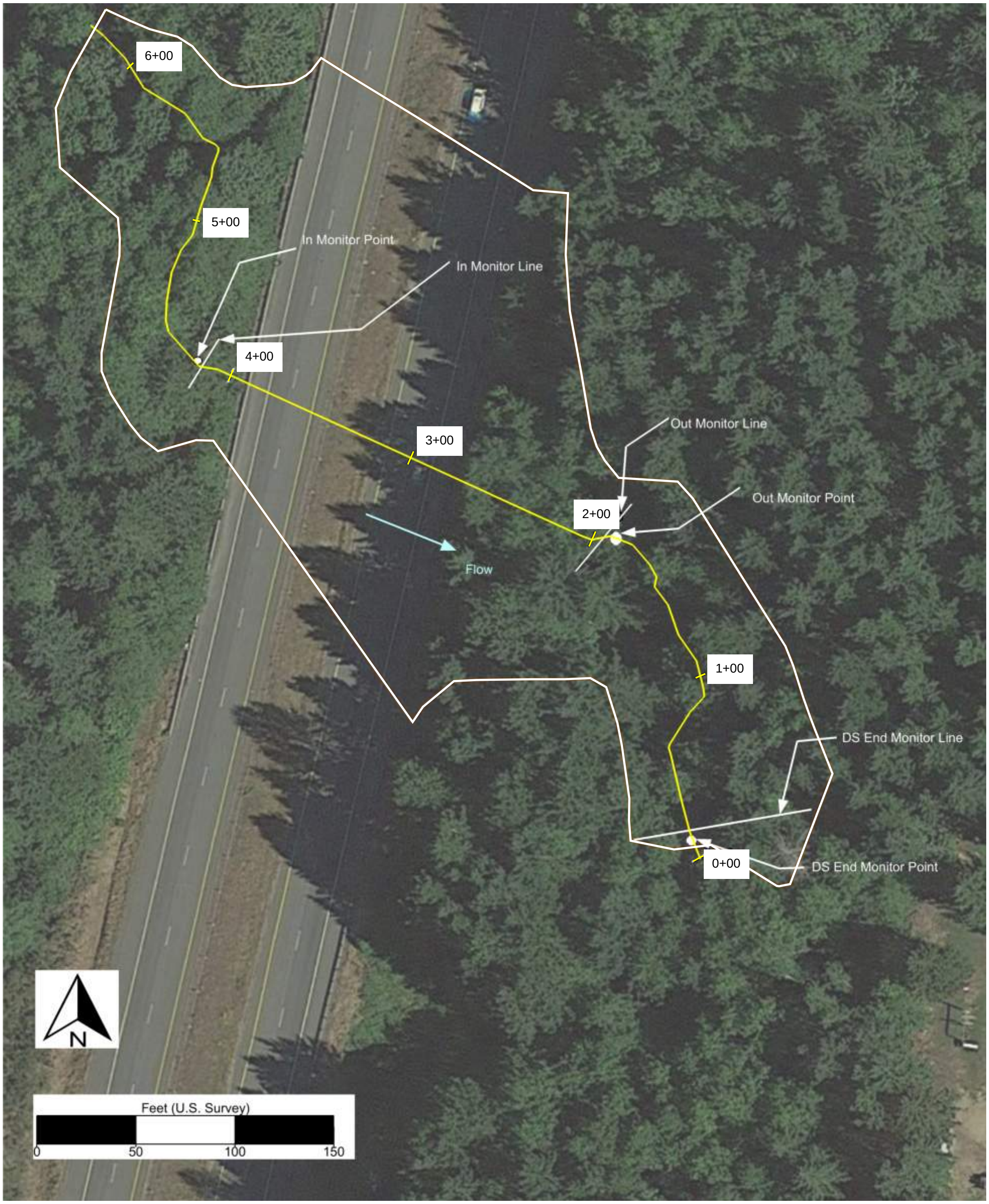
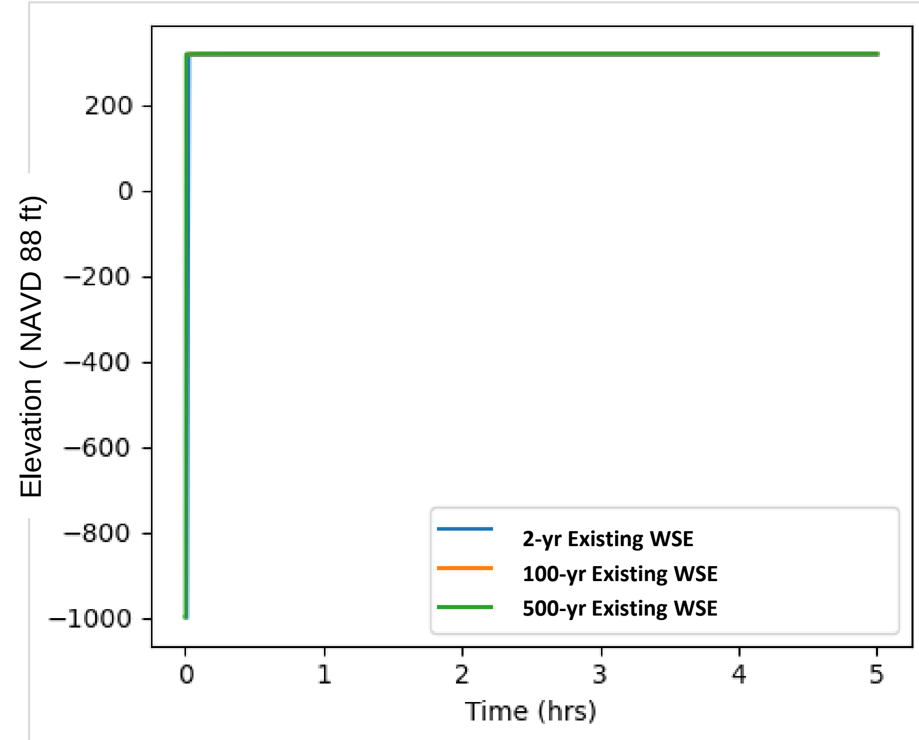
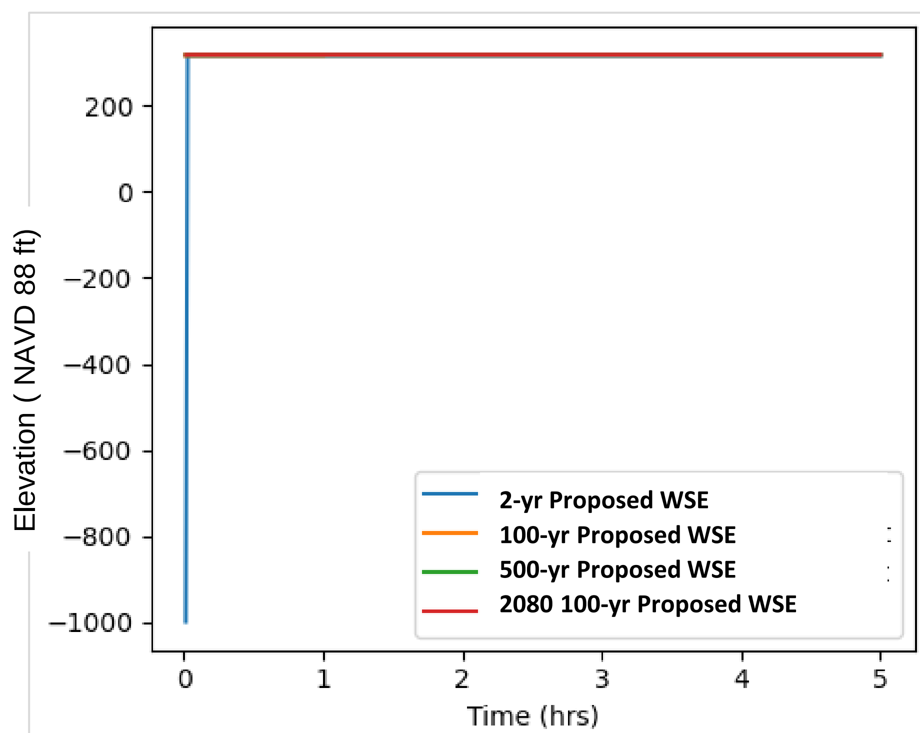


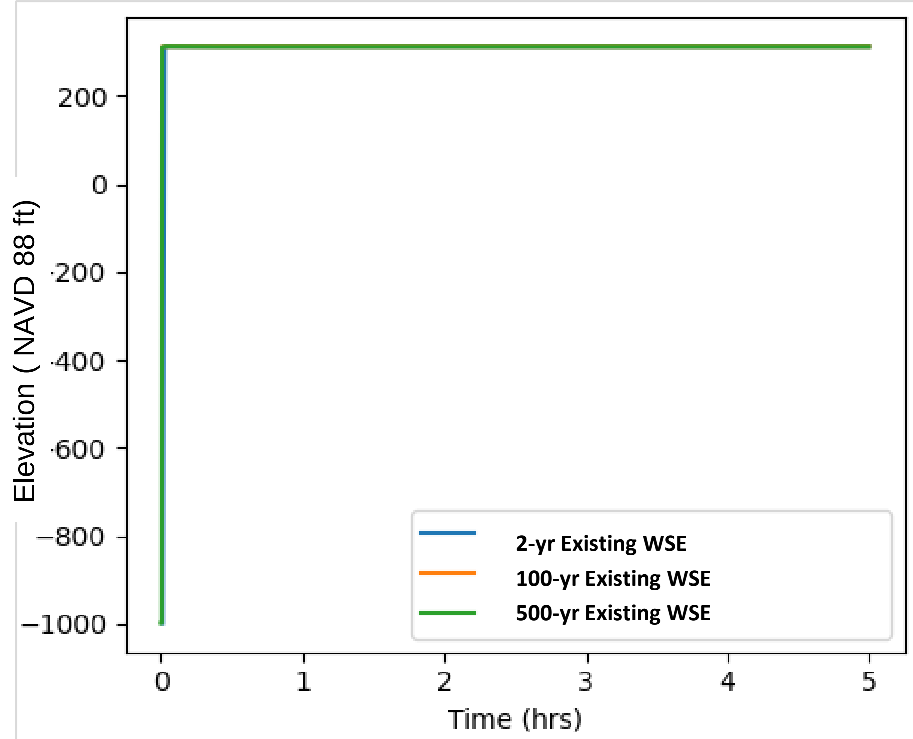
Figure I.1: Monitor Line and Point Locations



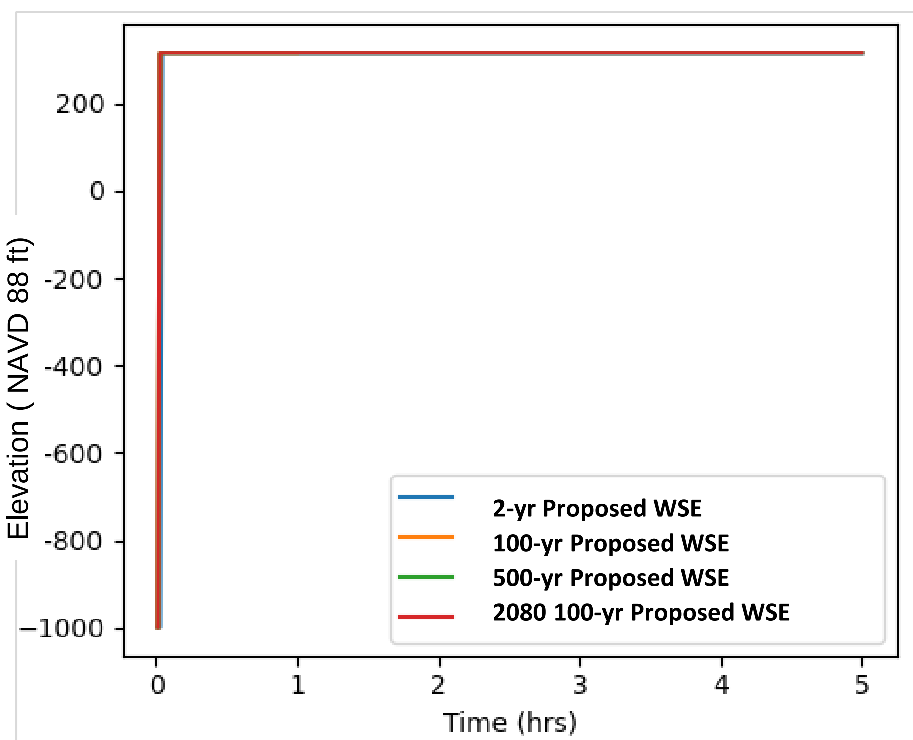
In Monitor Point



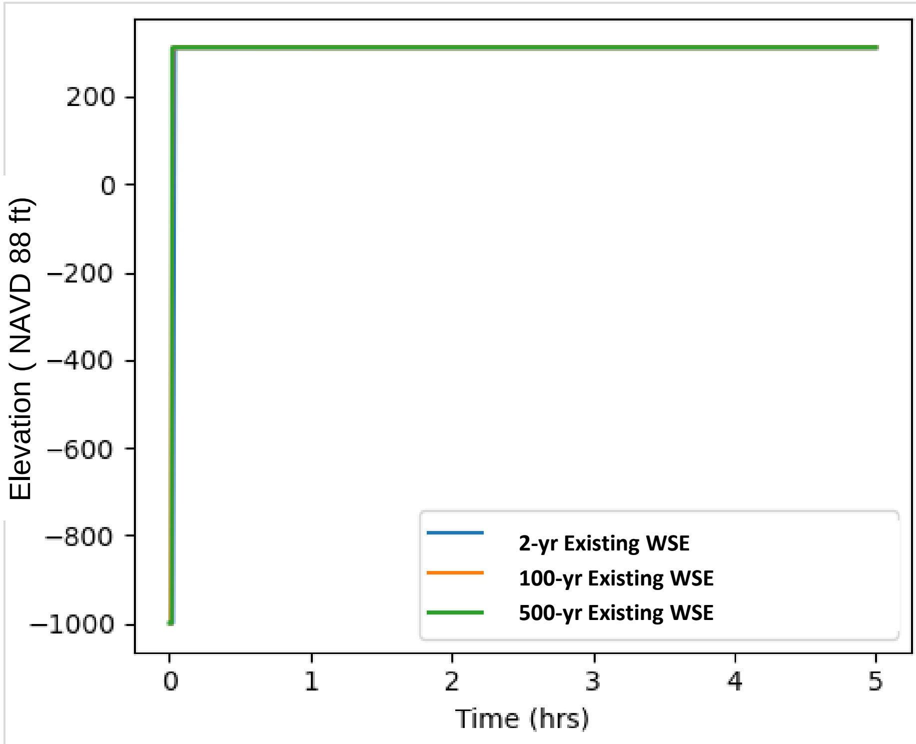
In Monitor Point



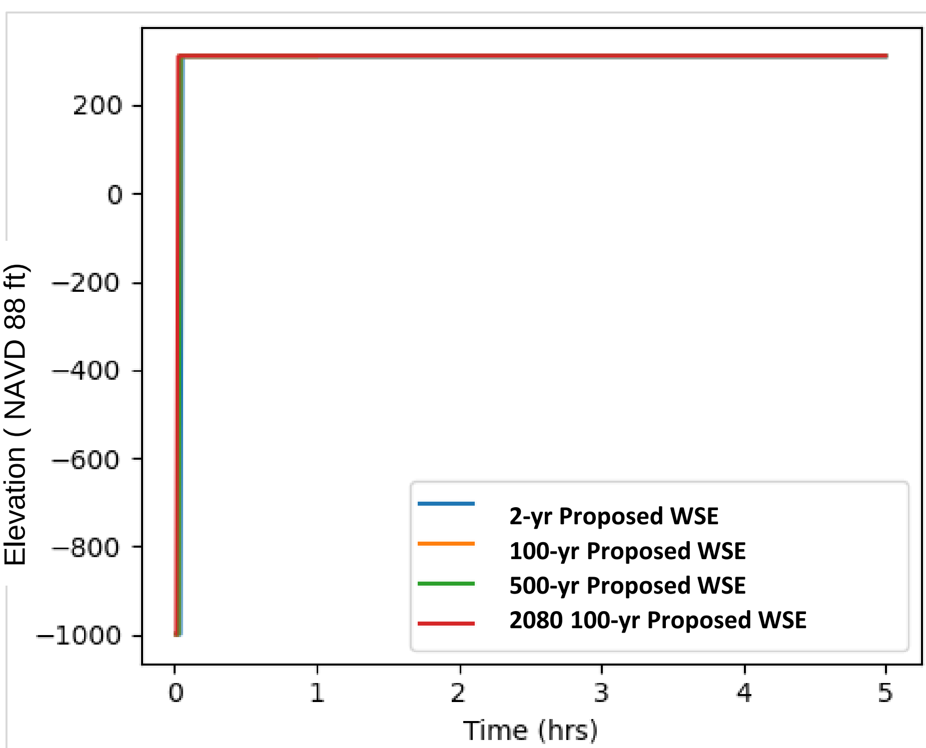
Out Monitor Point



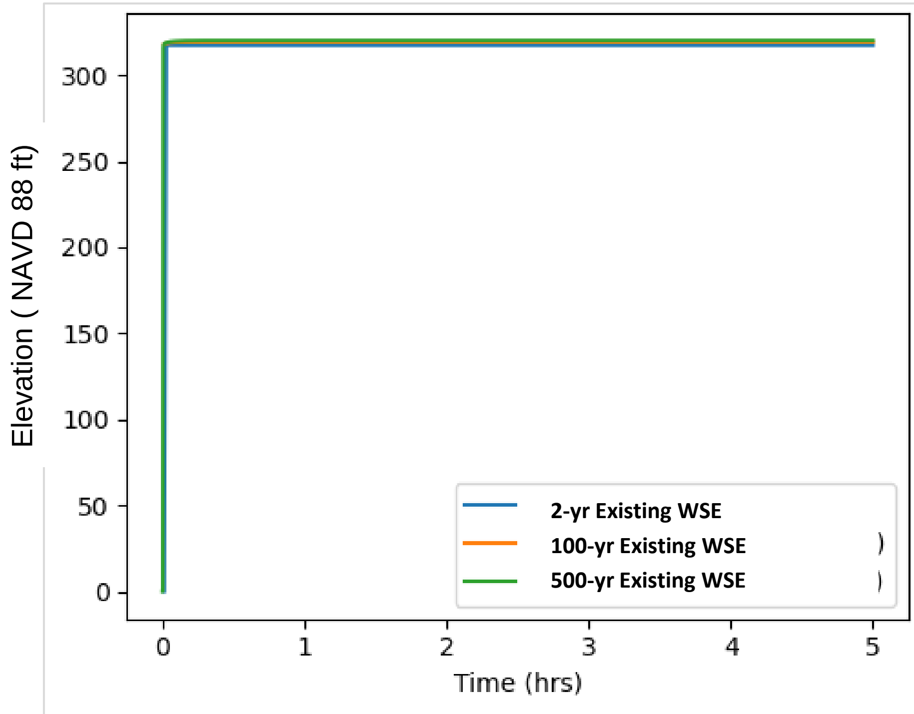
Out Monitor Point



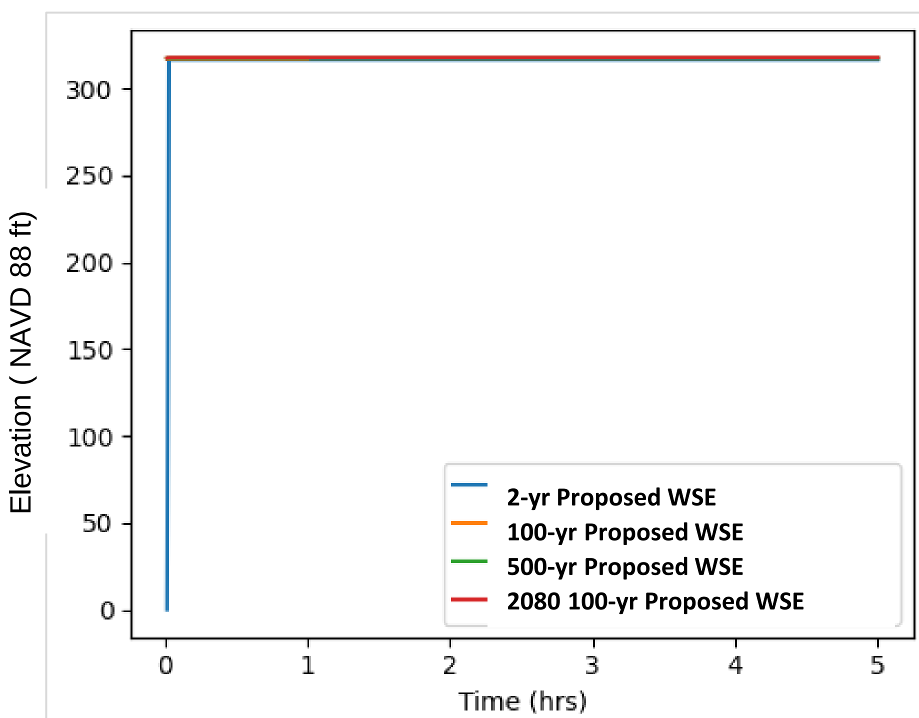
DS End Monitor Point



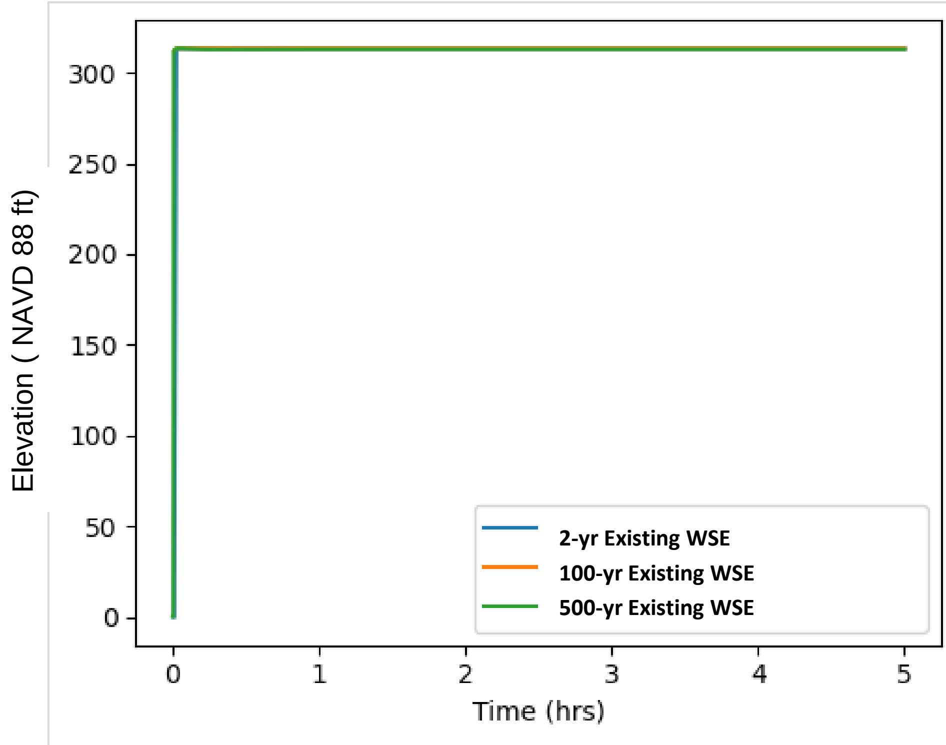
DS End Monitor Point



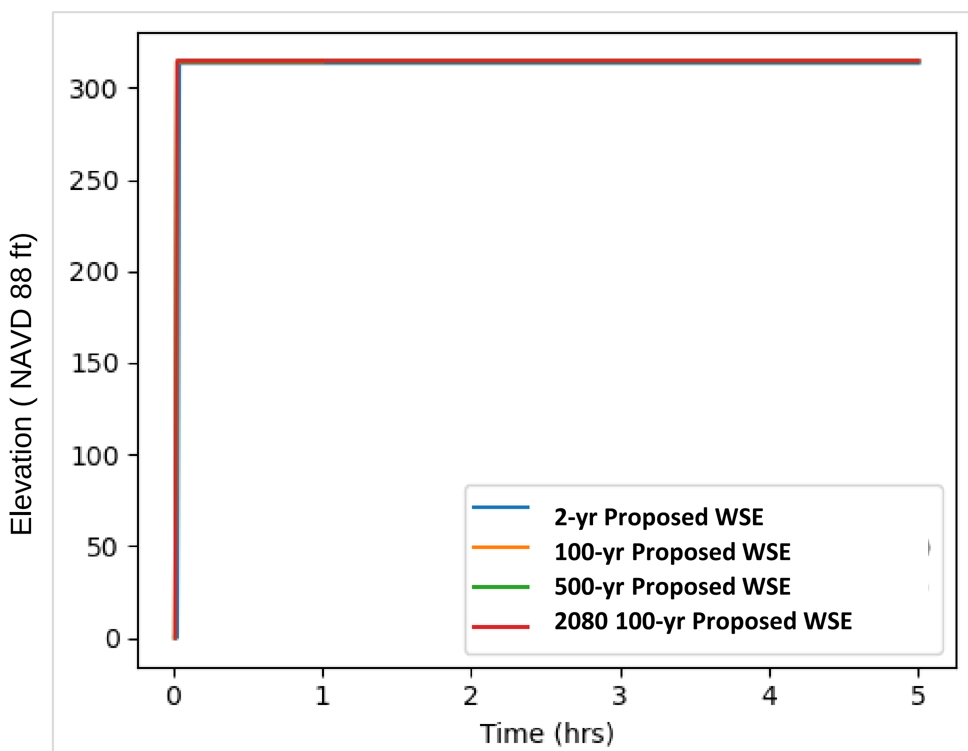
In Monitor Line



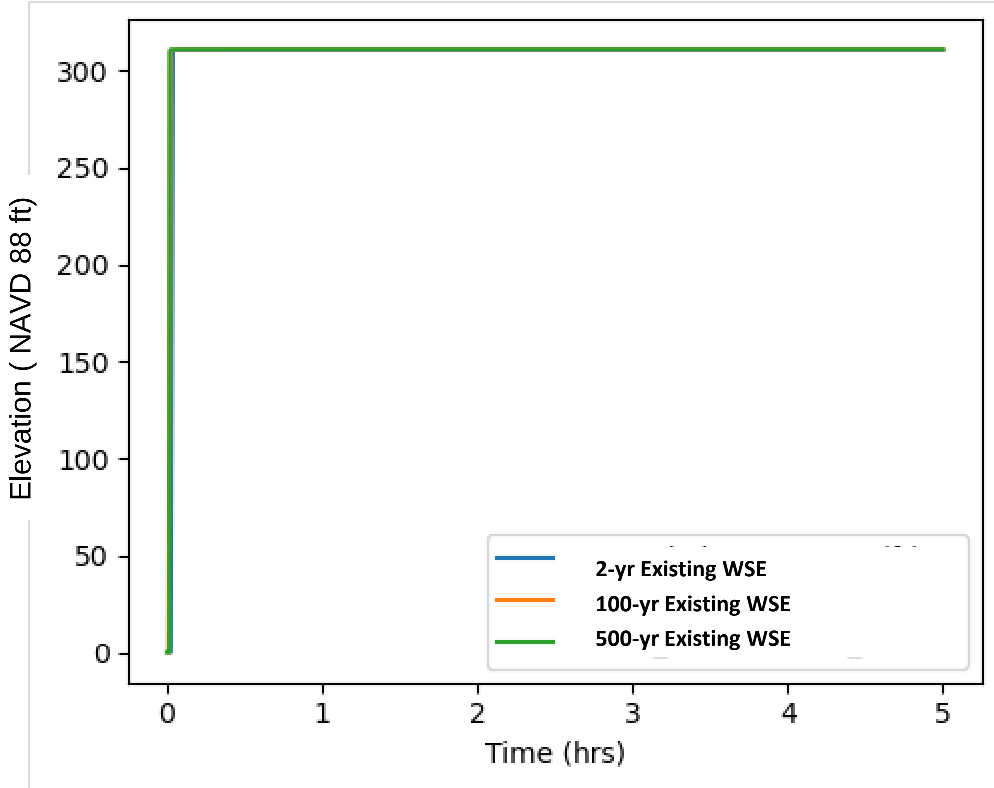
In Monitor Line



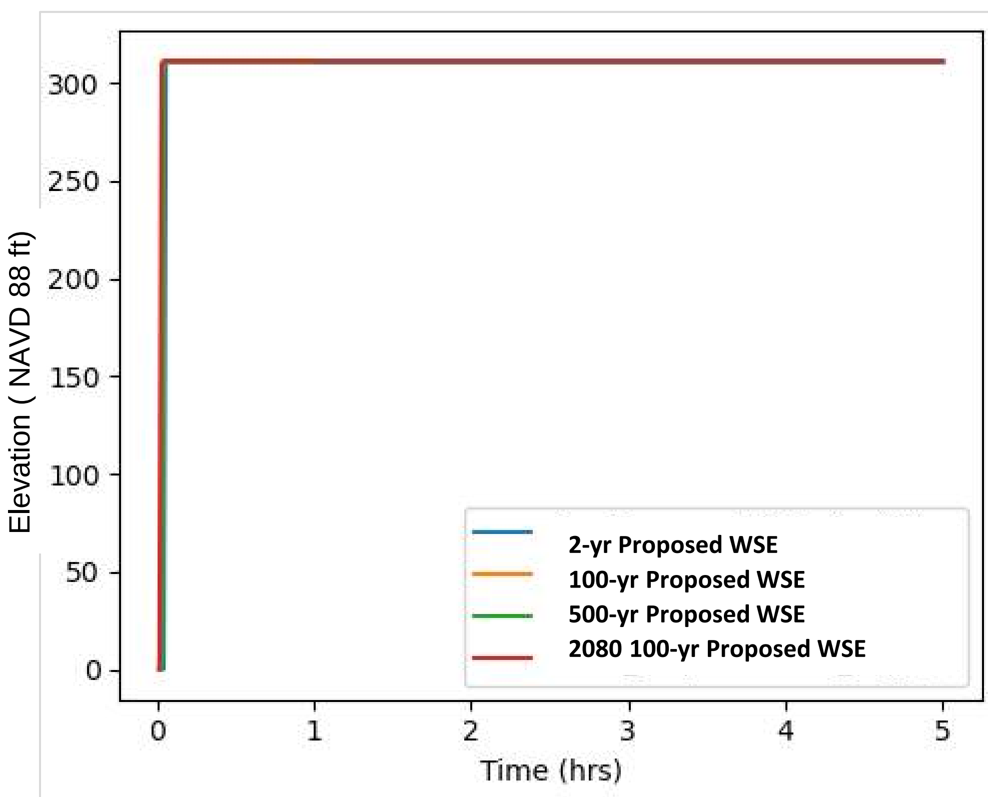
Out Monitor Line



Out Monitor Line



DS End Monitor Line



DS End Monitor Line

Appendix J: Reach Assessment

(Not used)

Appendix K: Scour Calculations

Not used. Will be done for the next round of review.

Appendix L: Floodplain Analysis

Not used. Will be done at a later stage of design.